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(Engineering Division, Association of American Railroads)

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* The contents of this Bulletin and subsequent Bulletins of the Association to and including Bulletin 614, June–July 1968 (except Bulletin 613, March 1968), will constitute the Annual Proceedings of the Association, Vol. 69. Accordingly, this issue of the Bulletin should be carefully preserved for inclusion in the Proceedings book-type binder which will be made available on request from the secretary's office, following publication of the June–July issue.

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Advance Report of Committee 3—Ties and Wood Preservation

K. C. Edscorn, *Chairman*

Termite Control Investigation—Inspection of Specimens After 112 Months of Exposure*

ABSTRACT

This is a report of progress in the 15-year investigation to determine the most effective preservative with minimum retention to be used in treating either oak, pine or fir species to reduce decay and termite attack. The results of the investigation after 112 months of exposure of the specimens are:

1. Specimens treated with coal-tar creosote show less decay and termite attack than specimens treated with other preservatives (see Table 7 and Figs. 2 to 13, incl.).

* AAR Research Department Report No. ER-73.

2. The diagrams on Figs. 2 to 13, incl., indicate that chromated zinc chloride and tanalith are affording less protection against decay and termite attack than the other preservatives.
3. In general, the fir specimens treated with most of the preservatives are subject to less decay and termite attack than the oak and pine specimens; however, oak is generally more resistant to decay and termite attack than pine or fir when not treated.
4. The average index rating increases with the amount of preservative in the specimens (see Fig. 14).
5. The analysis of one fir stake treated with pentachlorophenol indicates considerable loss in preservative in that part of the stake buried in the ground for 112 months.

INTRODUCTION

This report presents the results of an inspection of about 2,000 treated and untreated specimens in the exposure test plot of the Austin Cary Memorial Forest of the University of Florida near Gainesville, Fla., after about 112 months of exposure.

The report of the initial installation of 1296 treated specimens and 30 untreated control specimens, oak, pine and fir, placed in the exposure test plot in November 1957 is described in the 1959 Proceedings, Vol. 60, page 131. This detailed report covers the treatment of the specimens and chemical analysis of the preservatives. The specimens were treated with nine different preservatives using three different retentions for each preservative.

A supplemental installation of 576 treated specimens and 15 untreated controls, involving the use of four additional preservatives, was made in November 1959. A detailed report covering this installation may be found in the 1961 Proceedings, Vol. 62, page 95.

Detailed reports covering the inspection of the specimens after 40 months, 52 months, 64 months, 76 months, 88 months and 100 months are described in Engineering Research Division Reports ER-16, ER-23, ER-38, ER-46, ER-59 and ER-66, respectively, with the general conclusion in all six reports that those specimens treated with coal tar creosote showed more resistance to both decay and termite attack than those treated with the other preservatives.

The investigation is being conducted under the general direction of G. M. Magee, director of engineering research, Engineering Division, Research Department, AAR. The conduct of the investigation and preparation of the report were in charge of E. J. Ruble, executive research engineer, research staff, AAR. The inspection of the specimens was conducted on January 30 and 31, 1967, by Dr. J. B. Huffman of the University of Florida; three members of Committee 3—Ties and Wood Preservation—K. C. Edscorn, J. T. Slocomb and A. B. Baker; and E. J. Ruble and I. A. Eaton, research staff, AAR. Funds for the investigation are being provided by the AAR.

GRADING

The system of specimen grading for both decay and termite attack used during the inspection corresponds to that recommended by the American Wood Preservers Association. The code numbers and letters of the system are listed below, with the corresponding ratings developed by such grades:

Code No.	*Decay Grades*	*Rating, Percent*
1	Sound, no evidence of decay	100
2	Localized superficial decay	75
3	Slight but positive decay	50
4	Deep or severe decay	25
5	Failure, almost complete loss of strength	0

Code Letter	*Termite Attack Grades*	*Rating, Percent*
A	No attack	100
B	Slight termite attack	75
C	Moderate termite attack	50
D	Severe termite attack	25
E	Failure caused by termites	0

FIELD INSPECTIONS

The detailed inspection of the 2- by 4- by 18-in specimens was conducted primarily by Dr. Huffman and Mr. Eaton, with other members of the inspection party assisting by removing, cleaning and replacing the test specimens. The first member of the inspection party removed a specimen, each of which is buried vertically for half its length, from the ground and after cleaning off the dirt and sand with a spatula, handed it to Dr. Huffman. Dr. Huffman inspected and decided, with the help of the other members of the inspection party, the grade of the specimen for both decay and termite attack. Mr. Eaton tabulated the code number and code letter on field data sheets supplied by Dr. Huffman. The specimen was then replaced in its original position in the ground while the other members of the party pulled and cleaned the next stake. This procedure was repeated for the entire inspection.

An example of the tabulated decay and termite attack grades, as recorded in the field on the "Field Inspection Data Sheets" is shown on Table 1. The example shows the results of nine field inspections of the specimens in rows M, N, and O of plot 2. For example, in position 4 of row M, there is shown specimen O12D 21. As explained in the report covering the installation, the letter "O" designates oak species, "12" the stick number and "D" the fourth specimen cut from stick 12. The figure "2" designates the preservative number, which in this case is chromated zinc chloride. The figure "1" represents the retention used in the treatment and in this case is the lowest retention. The inspection of February 3, 1964, indicated this specimen had a grade of "5C", the "5" indicating failure due to decay with the "C" indicating moderate termite attack; consequently, the specimen was discarded and assumed to have a rating of "5E" for all inspections thereafter. As another example, there is shown in Table 1, row O, position 2, the pine specimen P101C 11 treated with the first or lowest amount of creosote. All inspections previous to the last inspection of February 15, 1966, indicated there was no decay or termite attack. The inspection of February 15, 1966 indicated that while there was no decay, there was evidence of some slight termite attack which resulted in a rating of "1B" as shown; however, the inspection of January 1967 did not indicate any termite attack so the specimen was again rated as "1A", as shown.

A close inspection of the Field Inspection Data Sheets indicates that many specimens were graded higher during the 1966 inspection than during the 1965 inspection, particularly with respect to termite attack; for example, see row N, position 2. In 1965 the specimen O61B 83 was graded as "3B" but in 1966 the grading was "3A", and in 1967 the grading was "5A", indicating failure due to decay but no termite attack. In general, upgrading from one year to the next year results from the destruction of physical evidence of former termite attack by the progression of decay fungi. Some difficulty is encountered during inspections in determining whether or not the insect galleries in decayed portions of the specimens were caused by termites or ants. If the termites or ants were present during the inspection, a decision could readily be made but if they were not present, and the usual tell-tale signs were not indicated, the cause of the galleries could not be definitely determined. Research has shown that ants frequently seek shelter or build nests in decayed wood while termites will drill through decayed wood to get to sound wood.

ANALYSES OF FIELD INSPECTION DATA

The data on the decay and termite attack grades, as recorded on the Field Inspection Data Sheets, were summarized and recorded on the "Classified Data Sheets," an example of which is shown on Table 2. The ratings for both decay and termite attack, in percent, were determined in the manner shown above under "Grading."

In the 12-, 25- and 40-month reports, the average index rating was obtained by averaging the decay rating with the termite attack rating. This procedure was slightly in variance with the recommendation of ASTM Specification, D 1758–60, Evaluating Wood Preservatives by Field Tests. The ASTM recommendation states that the decay and termite grades be combined, that is, the lowest grade from either cause be used, and all subsequent average index ratings for our annual inspections are in accordance with the ASTM recommendation.

The data on Table 2 show the results of the inspection of all specimens treated with preservative No. 2, chromated zinc chloride having a No. 1 retention. It can be seen that previously mentioned specimen O12D/21 is included under the oak species, the second from the top, with a grade of "5C" assigned to it during the inspection of February 1964 and "5E", complete failure, thereafter. The other nine specimens of like species and preservative retention are also shown accompanied by their respective grade. A summary of the grades for this preservative retention and species for the January 31, 1967 inspection is as follows:

9 specimens having a grade of "5E" (complete failure)
1 specimen having a grade of "3C"
—
10 specimens

The ratings for decay and termite attack were obtained in the following manner:

Decay	Termite Attack
Nine (5) at 0 = 0	Nine (E) at 0 = 0
One (3) at 50 = 50	One (C) at 50 = 50
50 ÷ 10 = 5.0	50 ÷ 10 = 5.0

The average index rating was obtained by combining the decay and termite grades, using the lowest grade for each, in the following manner:

Nine (5 or E) at 0 = 0
One (3 or C) at 50 = 50
—
50 =10 ÷ 5.0

RESULTS OF INSPECTION

Untreated Controls

The decay and termite attack ratings with their average index ratings for the untreated controls installed in February 1963 are shown in Table 3. The values shown in this table are the average of five oak, five fir and five pine specimens and indicate the general decline in the condition of the specimens over a period of four years. Most of the specimens had completely failed after three years and all but one fir specimen had failed after four years.

The data for the untreated specimens installed in February 1964 are shown in Table 4. It can be seen that the rapid rate of termite attack and decay continued through the third year. The average index ratings after 36 months of exposure are slightly higher than the ratings for the specimens installed in February 1963 at the end of 36 months; however, more failures have occurred in those specimens installed in February 1964.

The data for the untreated specimens installed in February 1965 are shown in Table 5 while the data for the specimens installed in February 1966 are shown in Table 6. It is interesting to note that the termite attack and decay are following the same pattern as the other installations after the same number of months of exposure. About one-half of the specimens can be expected to fail after 36 months of exposure with complete failure of all the specimens occurring after 48 months of exposure.

Treated Specimens

The decay and termite attack ratings after 112 months of exposure of the specimens treated with preservatives 1 to 9, incl., and after 87 months of exposure of specimens treated with preservatives 10 to 13, incl., are tabulated on Table 7. Typical pictures of decay and termite attack are shown on Fig. 1.

The data tabulated in Table 7 for the specimens treated with the No. 1 retention are shown graphically by the bar diagram on Fig. 2, those for the retention No. 2 on Fig. 3 and those for the No. 3 retention on Fig. 4. In studying Figs. 2, 3 and 4, it should be kept in mind that the No. 1 retention is only half that recommended by the AREA, retention No. 2 is the amount recommended, while retention No. 3 is 100 percent greater than the recommended amount. The bar diagrams indicate that decay and termite attack is now taking place in the specimens treated with coal-tar creosote, particularly in the oak and pine specimens with the No. 1 retention. Even the oak specimens with the No. 3 retention are showing slight decay. It can be seen that the oak and pine specimens treated with the No. 1 retention of tanalith have failed. The oak and pine specimens treated with No. 1 retention of chromated zinc chloride are also near failure. Considerable termite attack and decay has taken place in the specimens treated with the No. 1 and No. 2 retentions of pentachlorophenol, copper napthenate, acid copper chromate, ammoniacal copper arsenite, chromated zinc arsenate and chromated copper arsenate. The specimens treated with the No. 3 retention of most of the preservatives are now showing some termite attack, and decay, with the specimens treated with chromated zinc chloride, tanalith and chromated zinc arsenate showing more than the others.

A careful study of the quality index ratings, as shown on Figs. 2, 3 and 4, clearly indicates that the oak specimens are more subject to decay than the fir or pine specimens for all preservatives and all retentions.

The data on the specimens treated with various combinations of creosote with petroleum or coal tar indicate considerable variation, but it can be seen that these preservatives do not afford the protection given by coal-tar creosote. It is evident that such combinations afford more protection against termite attack than decay.

The diagrams on Figs. 5 to 13, incl., show the progressive decrease in the quality index ratings for all 3 species of wood and the three retentions of all 13 preservatives. The original test specimens treated with the 9 preservatives have been exposed 112 months while the specimens treated with the combinations of creosote and coal tar or petroleum have been exposed 87 months. It can be seen from Fig. 5 that the oak specimens treated with the No. 1 retention of creosote resisted decay and termite attack for 52 months but since that time there has been a gradual decrease in the rating. By projecting the line showing the decrease, it appears that the specimens will be completely gone after 190 months of exposure. For comparison, the oak specimens treated with tanalith have completely failed after 100 months of exposure and the oak specimens treated with chromated zinc chloride are very close to failure. It is obvious from the diagrams on Fig. 5 that the oak specimens treated with the No. 1 retention of creosote are showing more resistance to decay and termite attack than those treated with the other preservatives.

The decline in the quality index ratings of the fir specimens treated with the No. 1 retention is shown on Fig. 6. It can be seen that the specimens treated with creosote or ammoniacal copper arsenite (chemonite) are showing considerable resistance to decay and termite attack, but the ratings of the specimens treated with the other preservatives are only slightly higher than those for the oak specimens.

The decrease in ratings for the pine specimens treated with the No. 1 retention is shown on Fig. 7. In general, these specimens have about the same ratings as the oak specimens. The specimens treated with preservative 10 (60 percent creosote and 40 percent coal tar) indicate a higher index rating than those treated with preservative 1 (coal-tar creosote) but this rating is decreasing rapidly.

The decrease in the quality index ratings for the other retentions of preservatives is shown on Figs. 8 to 13, incl. It can be seen that there is some reduction in the ratings of the specimens treated with most of the preservatives.

The diagrams on Fig. 14 indicate the effect of varying the amount of preservative retention on the average index ratings after 112 months of exposure, the solid lines showing the effect for each of the nine preservatives and the dashed lines showing the effect for the average of the nine preservatives. It can be seen that, in general, the index ratings for all three species increased with an increase in preservative retention.

RESIDUAL PRESERVATIVE RETENTION

The original program for the investigation of termite control included laboratory tests on treated specimens removed from the exposure plot after 5 years, 10 years and 15 years, the end of the exposure time. Funds were not available for these laboratory tests at the end of the 5-year exposure time but consideration is now being given to the conduct of the tests at the end of the 10-year exposure time.

In order to work out a laboratory procedure annd estimate the costs of conducting such an investigation, one 2- by 4- by 18-in fir stake treated with No. 2 retention of pentachlorophenol was removed from the test plot during the January 1967 inspection and shipped back to the AAR Research Center. The number of the stake was F120E/42 and originally retained 9.8 lb of preservative solution or 0.49 lb of dry pentachlorophenol, as determined at the time of treatment at the Forest Products Laboratory.

The method of analysis used in determining the amount of preservative remaining in the stake was in agreement with the American Wood Preservers Association, A5-64, Standard Method for the Analysis of Pentachlorophenol by Copper–Pyridine Method. In general the copper–pyridine method is based on the formulation of a copper–pyridine–chlorophenol complex that is insoluble in water but readily soluble in chloroform, to which it imparts a brownish–yellow color. The total absorption of the brownish–yellow color complex that is formed is relative to the quantity of pentachlorophenol present, and this quantity is then determined by a spectrophotometer, as shown in Fig. 15.

The amount of remaining preservative in the stake is based upon four small samples removed from the stake, each sample being 1- by 1- by ¼ in, with the ¼ in thickness through the 4-in width of the stake. One sample was taken in the center portion of the stake at a location 4½ in from the bottom and another sample on the edge. The third sample was taken in the center portion at a location 4½ in from the top and the fourth sample on the edge. The four samples were then milled into sawdust separately and then analyzed. The results of the analyses, in pounds of dry pentacholorphenol per cubic foot, are as follows:

1. Bottom location—center = 0.152
2. Bottom location—edge = 0.075
3. Top location—center = 0.490
4. Top location—edge = 0.304

As previously mentioned, the stake retained, on the average, 0.49 lb per cut ft of dry pentachlorophenol when originally treated, and it can be seen that the center portion of the stake above the ground had retained the full amount of preservative after 112 months of exposure. The outer edges of that portion of the stake buried in the ground for 112 months had lost about 85 percent of the original preservative retained.

CONCLUSION

From the data secured, during the inspection of treated specimens of oak, fir and pine species after 112 months of exposure, it seems logical to conclude that:

1. Coal-tar creosote is affording more resistance to decay and termite attack than the other preservatives.

Table 1
TERMITE CONTROL INVESTIGATION

AAR RESEARCH CENTER
FIELD INSPECTION DATA SHEET

Plot 2

Location		Code	Rating of Condition of Specimens on Indicated Date								
Row	Position	Number	1-8-59	11-13-59	2-21-62	2-5-62	2-4-63	2-3-64	2-8-65	2-15-66	1-30-67
M	1	P94F/32		1A	1C	1B	3C	3C	3C	5C	*
	2	P40G/92		1A	1A	1A	1A	1B	1C	2C	1C
	3	F103A/32		1A	1A	1A	1A	1A	1C	3C	3C
	4	O12D/21	1B	3C	3C	3B	4C	5C	*	*	*
	5	O107E/81		2A	3A	2B	3B	3B	3C	5C	*
	6	F24H/23			1A	1B	1B	1B	1C	2C	2C
	7	F56C/93			-	-	1A	1A	1A	1A	1A
	8	P70I/63			-	-	1A	1A	3B	3A	3C
	9	P58I/72		1A	1A	1A	1A	1A	2A	3A	3A
N	1	O103E/42		1A	1A	1A	1A	1A	1A	1A	1A
	2	O61B/83			-	-	2A	2A	3B	3A	5A
	3	O53G/53			-	-	1A	1A	1A	1A	1A
	4	O63E/33			3A	2B	3B	3C	3C	4C	4B
	5	F104E/31		1A	1B	2B	1C	3C	3C	3C	3C
	6	P48B/12		1A	1A	1A	1A	Removed to AAR Lab			2-5-63
	7	O7I/63			-	-	1A	1B	2B	2B	2B
	8	P42F/81		1A	3A	2C	3C	3C	3C	3D	5E
	9	O73B/31	1A	2B	3B	3C	3C	3C	3C	5C	*
O	1	F76D/31	1A	1A	1A	1B	1C	2C	3C	3C	3B
	2	P101C/11	1A	1A	1A	1A	1A	1A	1A	1B	1A
	3	F76C/32		1A	1A	1A	2B	3C	3C	3C	3C
	4	F10A/43			-	-	1A	1A	1A	1A	1A
	5	F51C/83			-	-	1A	1A	1A	1A	2A
	6	O13G/32		2A	3A	1B	3B	3B	3C	3D	4D
	7	O15G/91		1A	1A	1B	2B	3B	3C	1A	3C
	8	O66A/13			-	-	1A	1A	1A	1A	1A
	9	P42G/41		1A	2A	1B	1C	2C	3C	3C	3C
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										

Inspected By: ______________________

AWPA Rating Code:
Numbers 1 to 5 indicate degree of decay with Number 1 being sound - no evidence of decay
Letters A to E indicate degree of termite attack with A having no attack.
* Failed and Removed.

Table 2
TERMITE CONTROL INVESTIGATION

AAR RESEARCH CENTER
CLASSIFIED DATA SHEETS

Preservative No. 2 - Chromated Zinc Chloride
Retention No. 1

Species	Code Number	Plot Location	Retention lb. cu. ft.	Rating of Condition of Specimens on Indicated Date			
				2-3-64	2-8-65	2-15-66	1-31-67
Oak	O 7H	3J9	0.52	5C	*	*	*
	12D	2M4	0.48	5C	*	*	*
	15D	1A5	0.51	3C	3C	5D	*
	20D	8N9	0.48	3C	3C	5E	*
	21C	6J1	0.50	3C	5D	*	*
	23G	4C7	0.52	4C	4C	5C	*
	40G	1F5	0.53	3C	3C	3C	3C
	41D	5L5	0.52	5C	*	*	*
	67F	7C8	0.51	3C	4C	5C	*
	84B	9F6	0.48	4D	4D	5D	*
	Months of Service			76	88	100	112
	Av. Termite Rating			45.0	30.0	20.0	5.0
	Av. Decay Rating			30.0	22.5	5.0	5.0
	Av. Index Rating			27.5	22.5	5.0	5.0
	No. of Failures			3	4	9	9
Fir	F 31F	5I1	0.42	1C	2C	3C	3C
	33G	1K6	0.55	2C	3C	3C	1C
	44G	9G1	0.59	5D	*	*	*
	45G	9H6	0.48	3D	3D	3C	3D
	53G	7B1	0.44	2C	2C	3C	3C
	55E	10J7	0.49	1C	2C	3C	3C
	56G	4C5	0.55	3C	3C	3C	3C
	61E	8O5	0.55	2C	3C	3C	3C
	70C	4O7	0.54	3C	3C	3C	3C
	74G	10L5	0.52	3C	3C	3C	3C
	Months of Service			76	88	100	112
	Av. Termite Rating			45.0	42.5	45.0	42.5
	Av. Decay Rating			62.5	52.5	45.0	12.5
	Av. Index Rating			42.5	42.5	45.0	10.0
	No. of Failures			1	1	1	1
Pine	P 27I	2D3	0.50	3C	3C	5C	*
	28H	8L7	0.51	3D	3E	*	*
	31I	9I1	0.50	*	*	*	*
	33H	10F2	0.51	4E	*	*	*
	34I	4I7	0.51	5D	*	*	*
	37I	5C9	0.49	2D	5D	*	*
	38I	7D1	0.50	3D	3D	4E	*
	39J	3F8	0.51	4D	4E	*	*
	47H	10D3	0.50	3D	3D	3C	3C
	48H	3J8	0.49	4E	*	*	*
	Months of Service			76	88	100	112
	Av. Termite Rating			20.0	12.5	10.0	5.0
	Av. Decay Rating			35.0	22.5	7.5	5.0
	Av. Index Rating			17.5	10.0	5.0	5.0
	No. of Failures			4	7	9	9

AWPA Rating Code:

Numbers 1 to 5 indicate degree of decay with No. 1 being sound - no evidence of decay.
Letters A to E indicate degree of termite attack with A having no attack.
*Failed and Removed.

Table 3
SUMMARY OF INDEX RATINGS
UNTREATED SPECIMENS
INSTALLED: FEB. 1963

T = Termite or D = Decay	12 Months Exposure			24 Months Exposure			36 Months Exposure			48 Months Exposure		
	Oak	Fir	Pine	Oak	Fir	Pine	Oak	Fir	Pine	Oak	Fir	Pine
T	50.0	35.0	40.0	55.0	20.0	30.0	25.0	10.0	0	20.0	10.0	0
D	50.0	55.0	45.0	30.0	40.0	20.0	10.0	20.0	0	0	5.0	0
AV. INDEX	40.0	35.0	40.0	30.0	20.0	20.0	10.0	10.0	0	0	5.0	0
No. of Failures	0	1	1	2	3	2	3	3	5	5	4	5

Table 4
SUMMARY OF INDEX RATINGS
UNTREATED SPECIMENS
INSTALLED: FEB. 1964

T = Termite or D = Decay	12 Months Exposure			24 Months Exposure			36 Months Exposure		
	Oak	Fir	Pine	Oak	Fir	Pine	Oak	Fir	Pine
T	55.0	55.0	50.0	75.0	35.0	30.0	55.0	10.0	15.0
D	60.0	65.0	70.0	40.0	35.0	25.0	10.0	20.0	5.0
AV. INDEX	50.0	55.0	50.0	35.0	25.0	20.0	10.0	5.0	0
No. of Failures	0	0	0	1	1	2	4	4	5

Table 5
SUMMARY OF INDEX RATINGS
UNTREATED SPECIMENS
INSTALLED: FEB. 1965

T = Termite or D = Decay	12 Months Exposure			24 Months Exposure		
	Oak	Fir	Pine	Oak	Fir	Pine
T	50.0	50.0	50.0	62.5	35.0	30.0
D	75.0	55.0	50.0	50.0	35.0	25.0
AV. INDEX	50.0	40.0	50.0	50.0	10.0	20.0
No. of Failures	0	0	0	0	4	3

Table 6
SUMMARY OF INDEX RATINGS
UNTREATED SPECIMENS
INSTALLED: FEB. 1966

T = Termite or D = Decay	12 Months Exposure		
	Oak	Fir	Pine
T	66.6	45.0	60.0
D	58.3	60.0	60.0
AV. INDEX	58.3	45.0	50.0
No. of Failures	0	0	0

Table 7
SUMMARY OF QUALITY INDEX RATINGS
TREATED SPECIMENS

Pres.	Months of Service	T=Termite or D=Decay	No. 1 Retention			No. 2 Retention			No. 3 Retention		
			Oak	Fir	Pine	Oak	Fir	Pine	Oak	Fir	Pine
1	112	T	97.5	97.5	92.5	100.0	97.5	97.5	100.0	100.0	100.0
		D	67.5	92.5	67.5	75.0	95.0	97.5	97.5	100.0	100.0
		AV.	67.5	90.0	62.5	75.0	95.0	97.5	97.5	100.0	100.0
2	112	T	5.0	42.5	5.0	25.0	50.0	35.0	47.5	55.0	50.0
		D	5.0	42.5	5.0	35.0	55.0	35.0	45.0	77.5	72.5
		AV.	5.0	40.0	5.0	32.5	47.5	32.5	45.0	55.0	50.0
3	112	T	0	57.5	0	32.5	62.5	55.0	77.5	77.5	67.5
		D	0	47.5	0	15.0	45.0	47.5	40.0	60.0	52.5
		AV.	0	45.0	0	15.0	45.0	42.5	40.0	57.5	52.5
4	112	T	65.0	52.5	52.5	92.5	65.0	62.5	100.0	100.0	95.0
		D	52.5	65.0	60.0	67.5	75.0	65.0	95.0	100.0	85.0
		AV.	52.5	52.5	50.0	67.5	60.0	57.5	95.0	100.0	85.0
5	112	T	70.0	62.5	57.5	92.5	92.5	87.5	100.0	100.0	100.0
		D	50.0	65.0	50.0	70.0	95.0	87.5	85.0	100.0	100.0
		AV.	50.0	57.5	47.5	70.0	90.0	85.0	85.0	100.0	100.0
6	112	T	37.5	52.5	40.0	90.0	80.0	62.5	90.0	95.0	80.0
		D	37.5	47.5	40.0	57.5	100.0	75.0	87.5	100.0	97.5
		AV.	25.0	45.0	35.0	57.5	80.0	62.5	82.5	95.0	80.0
7	112	T	92.5	95.0	72.5	97.5	100.0	97.5	95.0	100.0	95.0
		D	50.0	85.0	60.0	57.5	92.5	67.5	65.0	100.0	90.0
		AV.	50.0	85.0	57.5	57.5	92.5	67.5	62.5	100.0	87.5
8	112	T	30.0	67.5	32.5	70.0	77.5	55.0	90.0	92.5	92.5
		D	27.5	47.5	25.0	45.0	57.5	47.5	40.0	70.0	62.5
		AV.	25.0	47.5	25.0	45.0	55.0	45.0	40.0	70.0	60.0
9	112	T	35.0	62.5	60.0	72.5	82.5	62.5	100.0	100.0	90.0
		D	25.0	67.5	60.0	42.5	77.5	77.5	95.0	100.0	97.5
		AV.	25.0	55.0	55.0	42.5	72.5	62.5	95.0	100.0	90.0
10	87	T	90.0	95.0	97.5	92.5	100.0	100.0	100.0	100.0	100.0
		D	50.0	95.0	87.5	55.0	100.0	97.5	67.5	100.0	100.0
		AV.	50.0	90.0	87.5	55.0	100.0	97.5	67.5	100.0	100.0
11	87	T	95.0	95.0	95.0	97.5	97.5	100.0	100.0	100.0	100.0
		D	50.0	97.5	75.0	70.0	100.0	92.5	72.5	100.0	100.0
		AV.	50.0	95.0	75.0	70.0	97.5	92.5	72.5	100.0	100.0
12	87	T	95.0	95.0	65.0	97.5	100.0	100.0	97.5	100.0	100.0
		D	50.0	97.5	60.0	52.5	100.0	95.0	67.5	97.5	100.0
		AV.	50.0	95.0	52.5	52.5	100.0	95.0	67.5	97.5	100.0
13	87	T	80.0	92.5	62.5	97.5	100.0	100.0	100.0	100.0	100.0
		D	52.5	85.0	50.0	60.0	97.5	92.5	65.0	100.0	100.0
		AV.	52.5	82.5	47.5	60.0	97.5	92.5	65.0	100.0	100.0

Specimens treated with preservatives 1 to 9 incl. were installed in November 1957.
Specimens treated with preservatives 10 to 13 incl. were installed in November 1959.
Inspection Date: January 1967.

Fig. 1 (a)—Oak specimen treated with chromated zinc arsenate, showing surface softness due to decay.

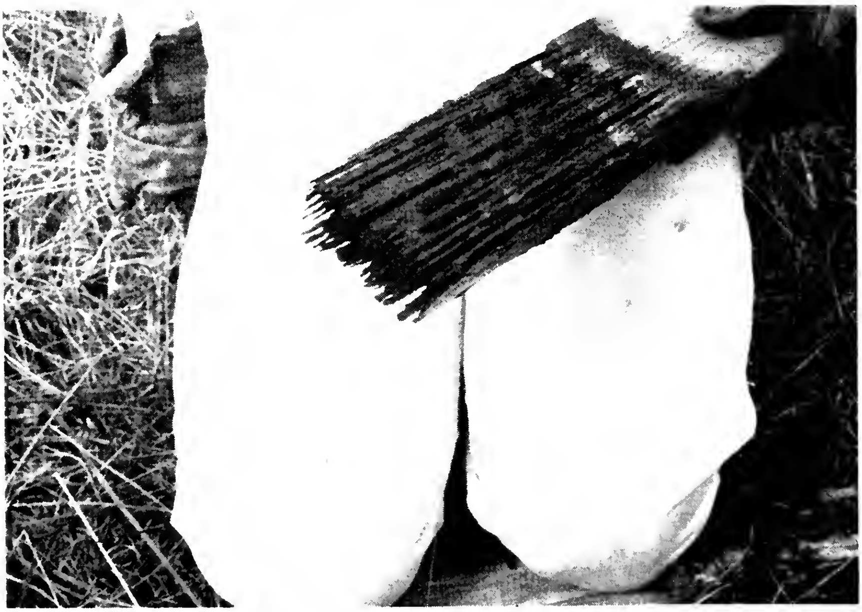


Fig. 1 (b)—Fine specimen treated with tanalith, showing failure due to termite attack and near failure due to decay.

FIG 2
SUMMARY OF QUALITY INDEX RATINGS
TREATED SPECIMENS
RETENTION: I

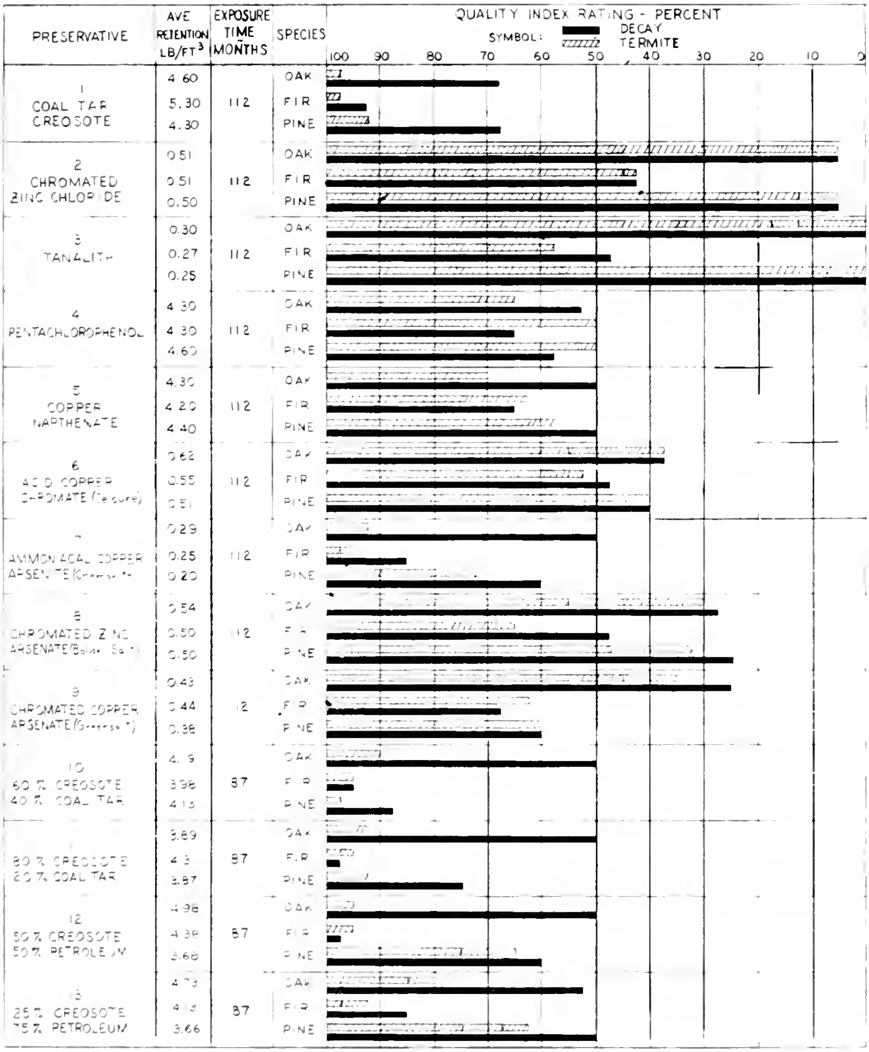


FIG 3
SUMMARY OF QUALITY INDEX RATINGS
TREATED SPECIMENS
RETENTION 2

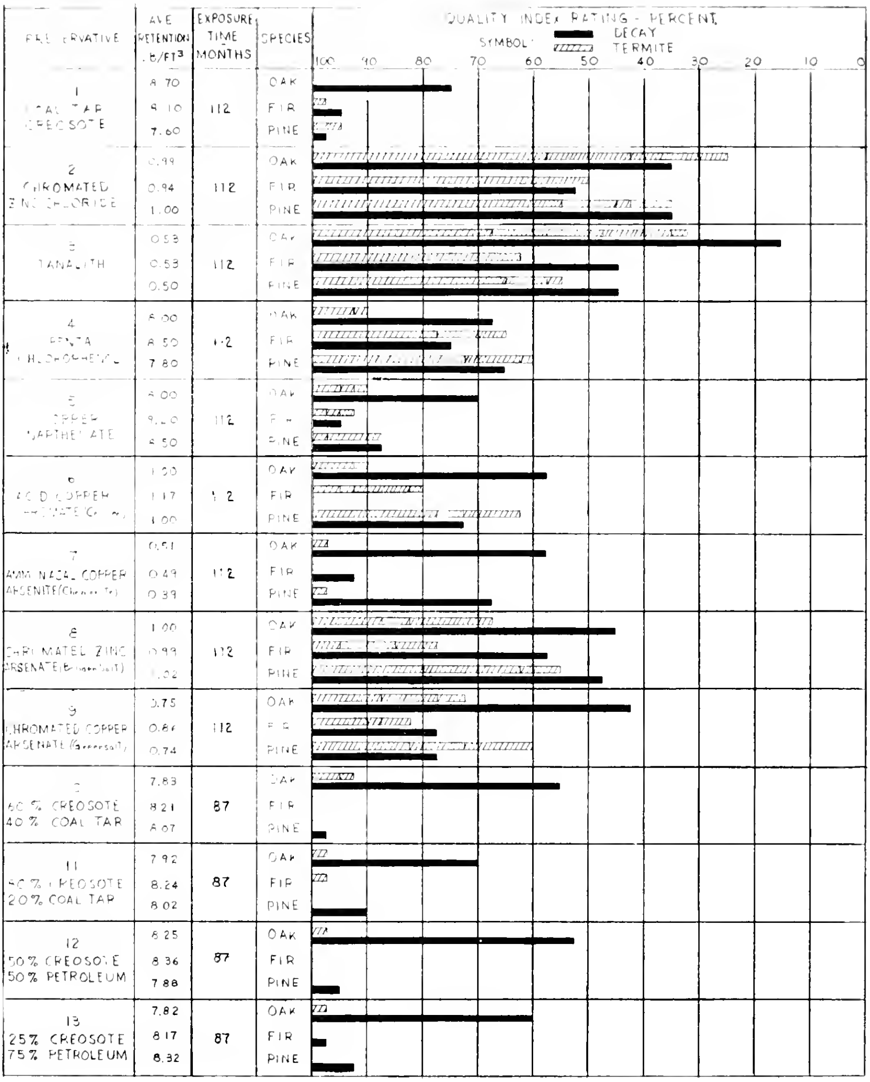


FIG 4
SUMMARY OF QUALITY INDEX RATINGS
TREATED SPECIMENS
RETENTION: 3

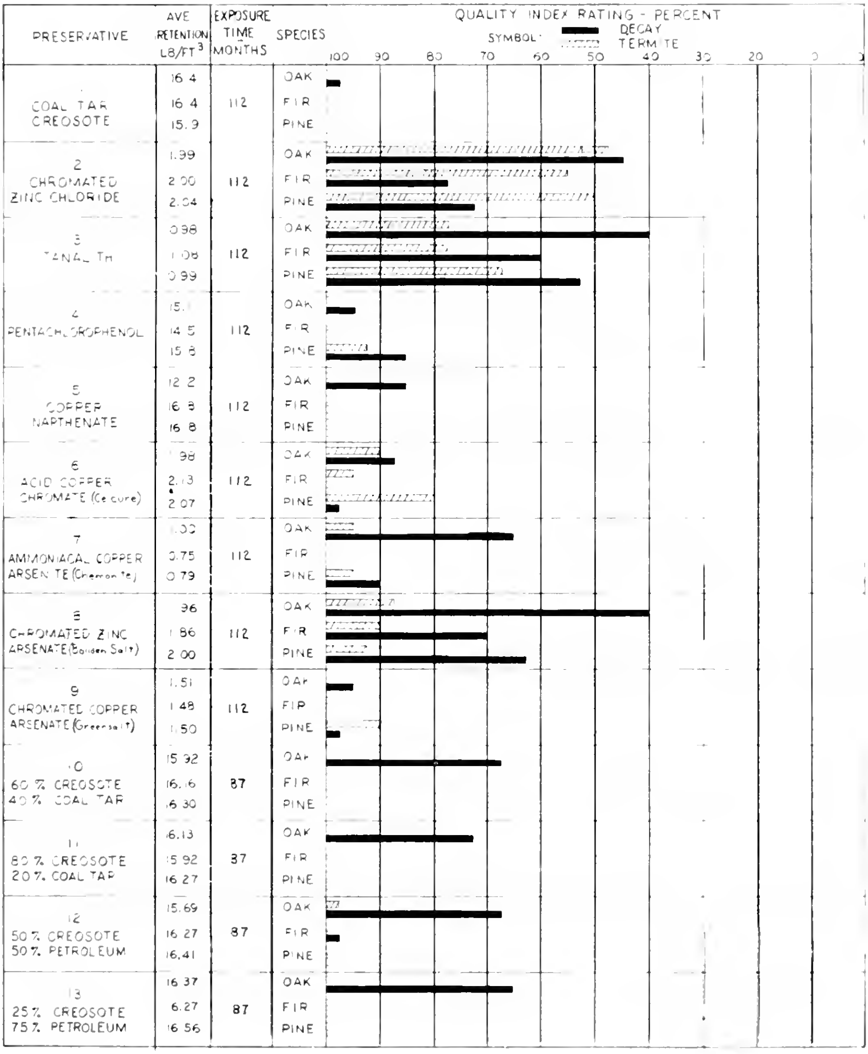


FIG. 5
AVERAGE QUALITY INDEX RATING
RETENTION NO. 1
OAK SPECIE

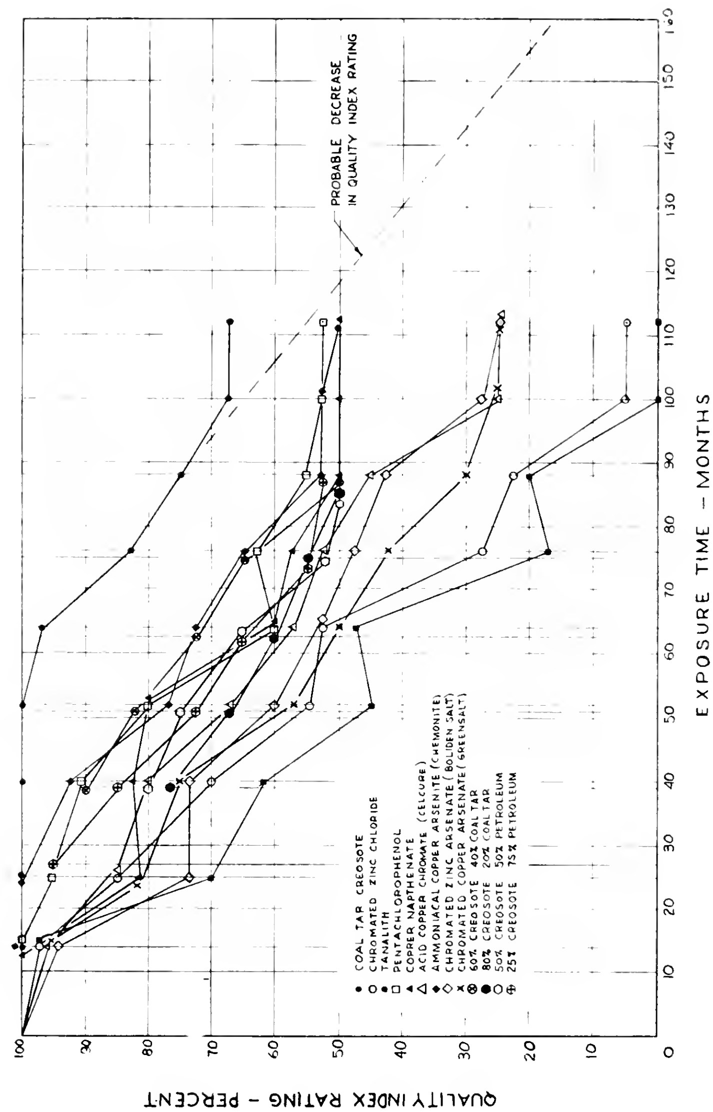


FIG. 6
AVERAGE QUALITY INDEX RATING
RETENTION NO. 1
FIR SPECIE

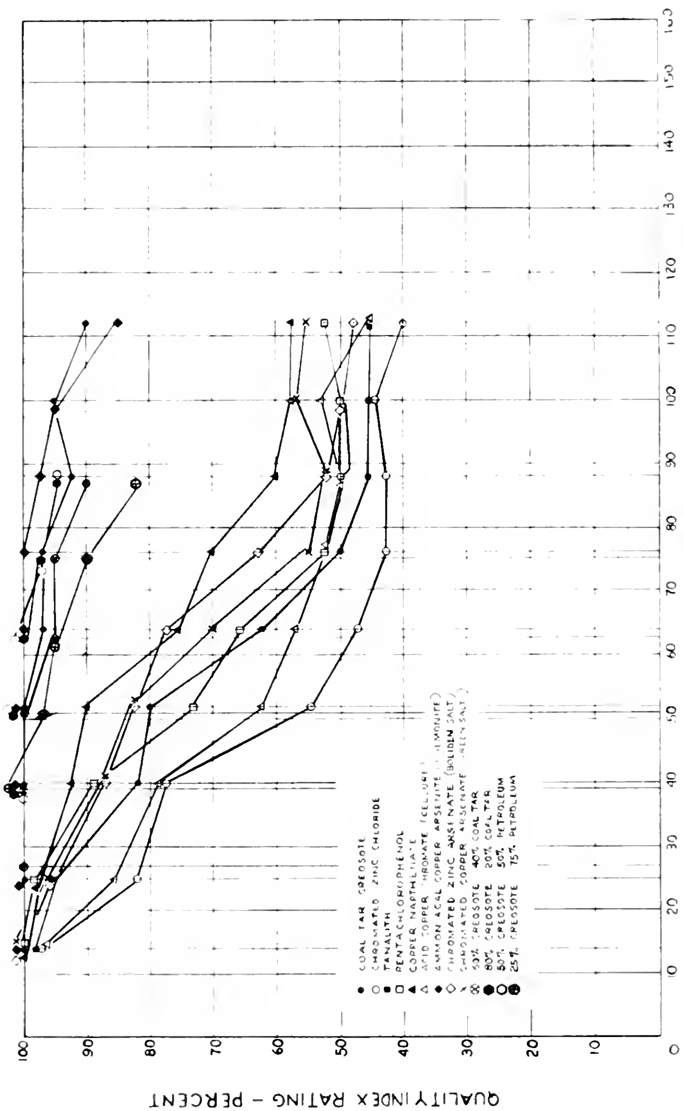


FIG. 7
AVERAGE QUALITY INDEX RATING
RETENTION NO. 1
PINE SPECIE

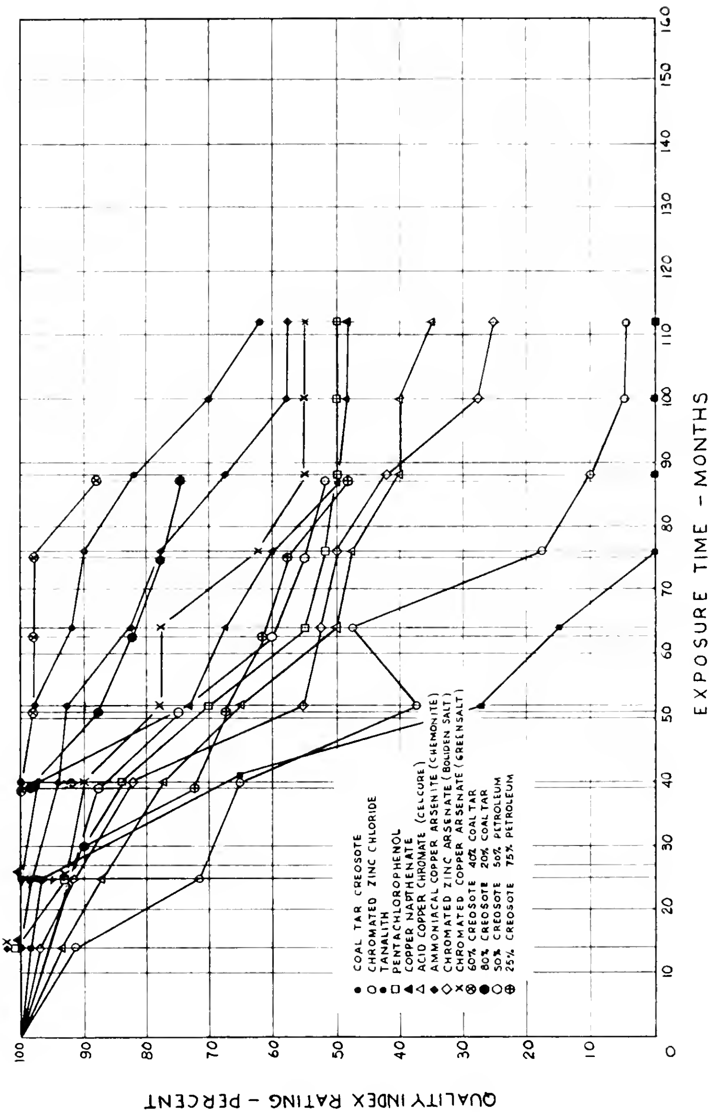
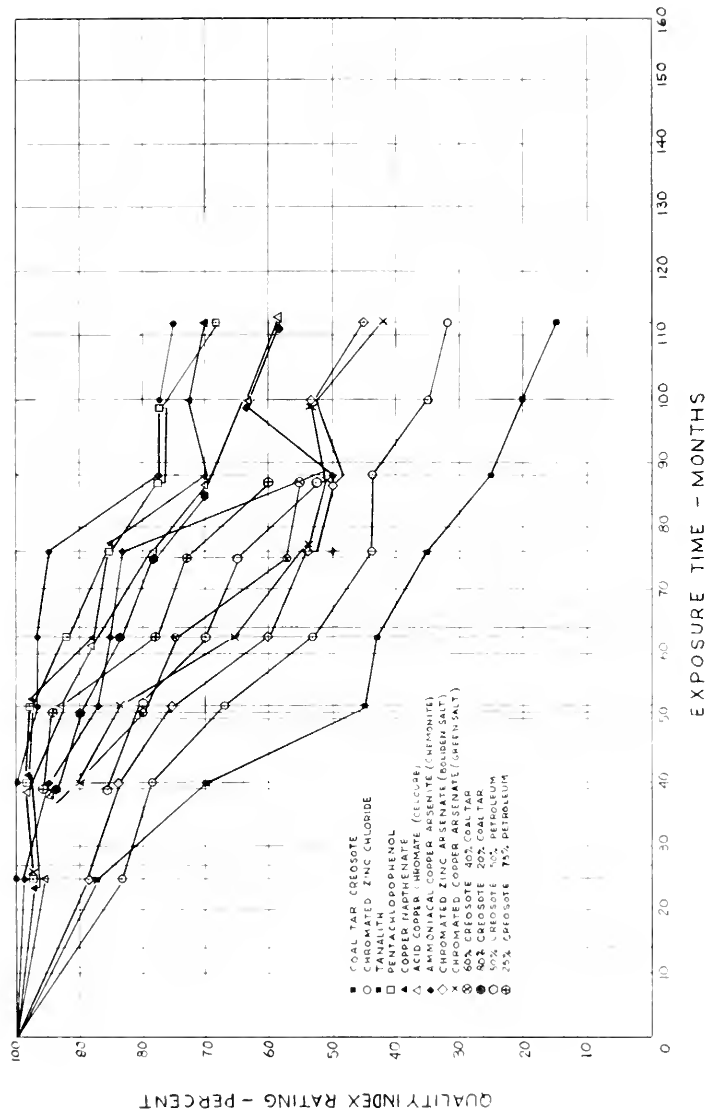


FIG. 8
AVERAGE QUALITY INDEX RATING
RETENTION NO. 2
OAK SPECIE



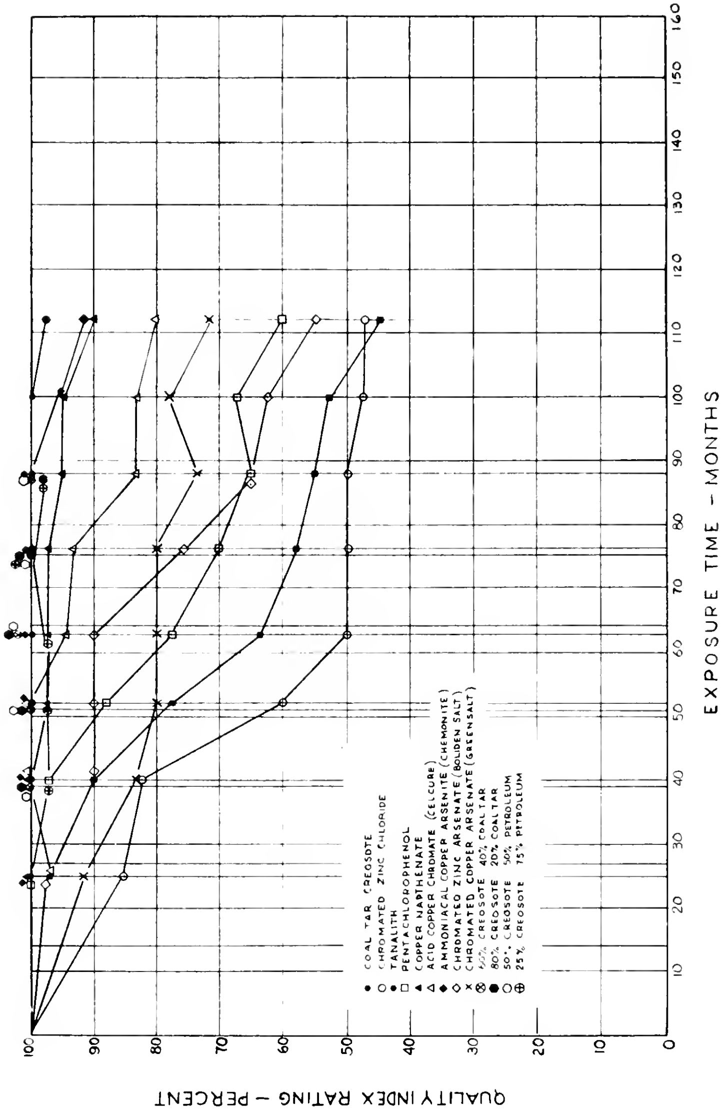


FIG 9
AVERAGE QUALITY INDEX RATING
RETENTION NO.2
FIR SPECIE

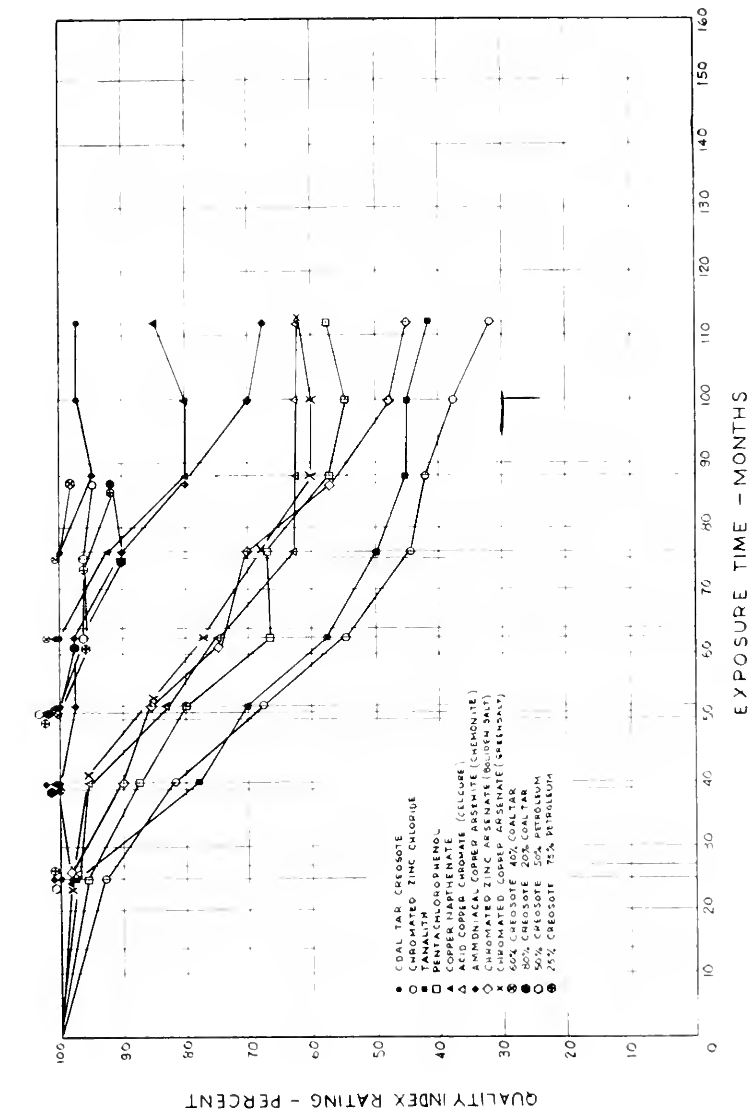


FIG. 10
AVERAGE QUALITY INDEX RATING
RETENTION NO. 2
PINE SPECIE

FIG 11
AVERAGE QUALITY INDEX RATING
RETENTION NO. 3
OAK SPECIE

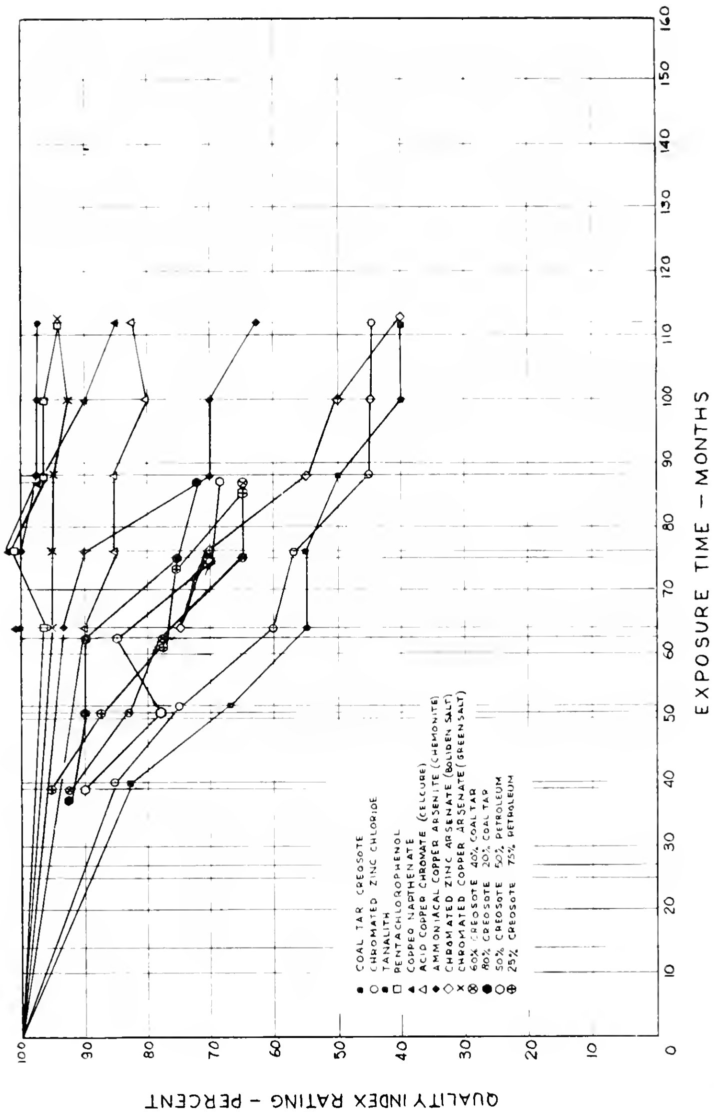


FIG 12
AVERAGE QUALITY INDEX RATING
RETENTION NO. 3
FIR SPECIE

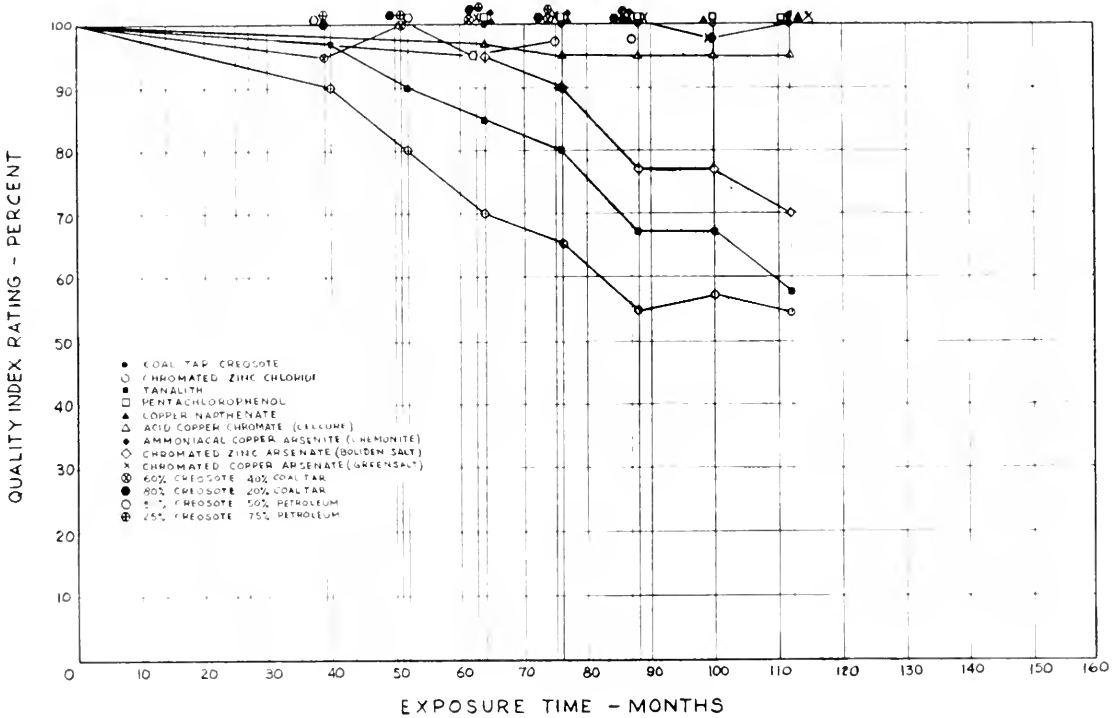


FIG. 13
AVERAGE QUALITY INDEX RATING
RETENTION NO. 3
PINE SPECIE

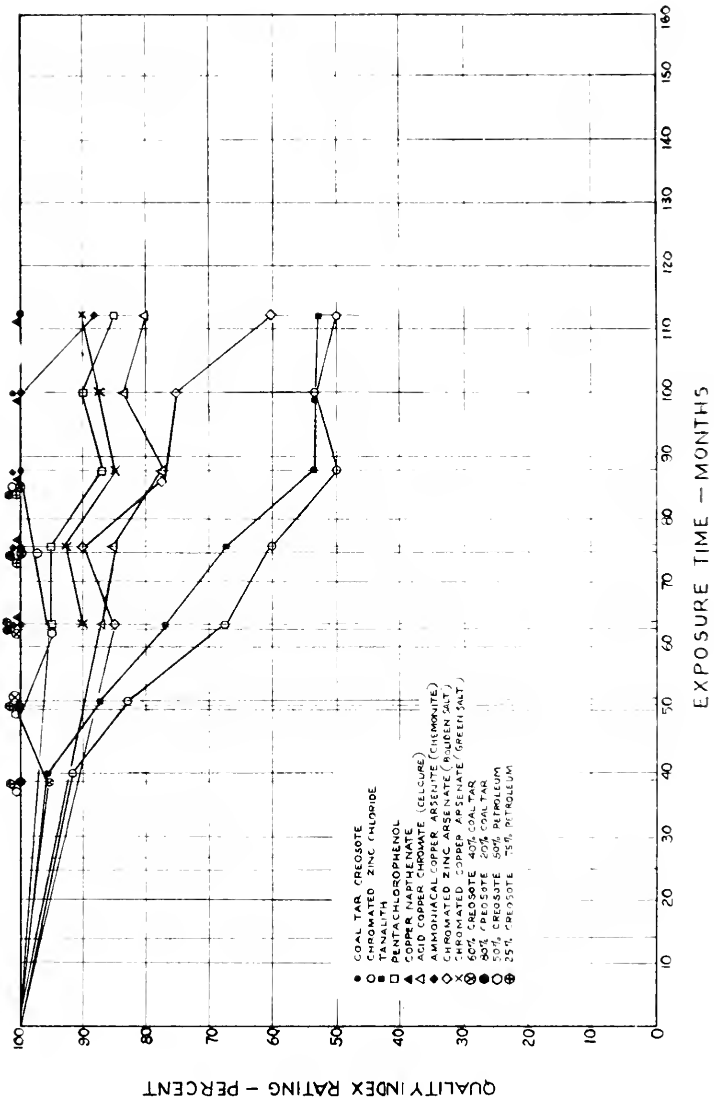
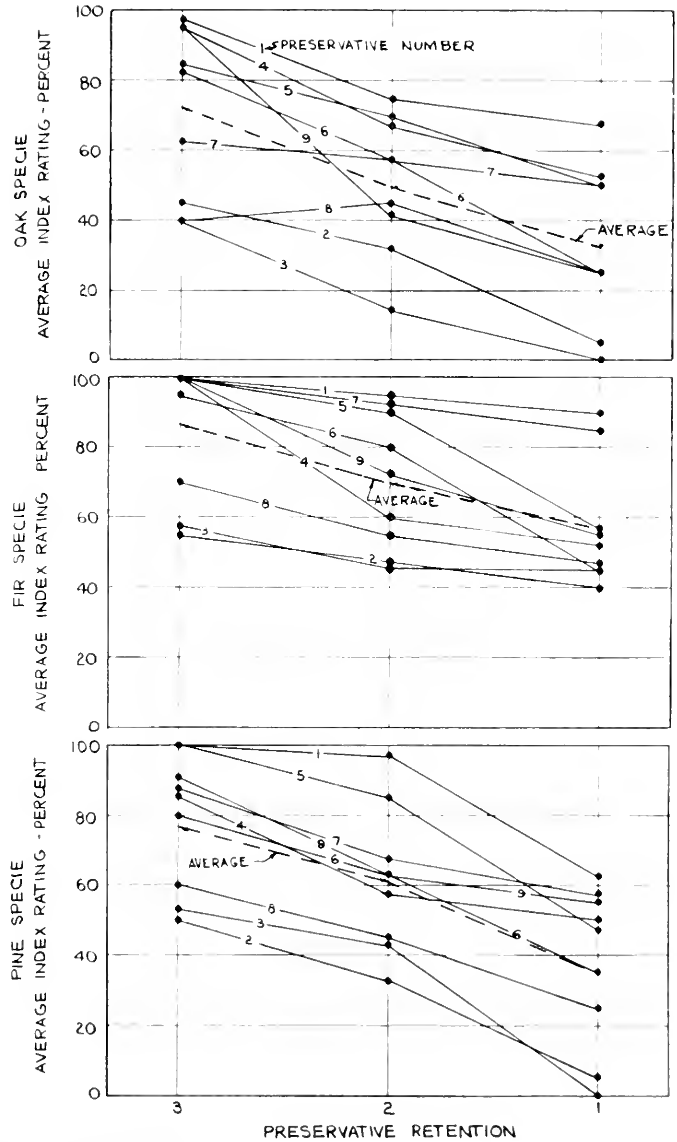


FIG. 14
EFFECT OF AMOUNT OF PRESERVATIVE ON INDEX RATING



NOTE: PRESERVATIVE RETENTION
1 - ½ A.R.E.A RECOMMENDED
2 - A.R.E.A RECOMMENDED
3 - 2 A.R.E.A. RECOMMENDED

Advance Report of Committee 7—Wood Bridges and Trestles

D. V. Sartore, *Chairman*

Use of Sonic Devices for Determining Internal Decay in Timber*

A. FOREWORD

The detection of internal decay in large structural timbers by non-destructive methods has been under study for several years by Committee 7—Wood Bridges and Trestles. Present methods of inspection involving drilling, probing, etc., are not only damaging to the timber but they also do not permit a thorough tracing of the extent of the decay.

In pursuance of the committee's assignment on non-destructive testing of wood, the AAR Research Center has studied both nuclear and sonic methods of detection and has evaluated certain commercial devices which have shown promise of practical application. A report on one such device which utilized a nuclear source was published in the AREA Proceedings, Vol. 65, 1964, p. 420. Some other proprietary devices are presently available which can be used for internal detection of decay. Two of these were demonstrated at the Research Center; both gave a fairly good indication as to whether or not decay was present. Neither one, however, would indicate the size of the internal voids nor did the manufacturers make any claim in this regard. Moisture in the wood or on the surface had no apparent effect on the instrument readings.

B. DESCRIPTION OF INSTRUMENTS

The two devices which were demonstrated are sold commercially under trade names and will be referred to in this report as Device "A" and Device "B". Both utilize the transmission of sound through the timber and are based on the principal that decayed or hollow pieces will divert and delay the sound wave and, hence, the measured time delay is a function of the internal condition of the timber.

Device "A"

The essential components making up this device are a console, a transmitter head, a receiving head and a power supply (see Fig. 1).

The console contains a cathode ray oscilloscope, a micro-second timer and other electronic circuitry. It weighs 23 lb and is portable, but in normal use it would be kept at a central location with cables to the points at which readings are to be taken.

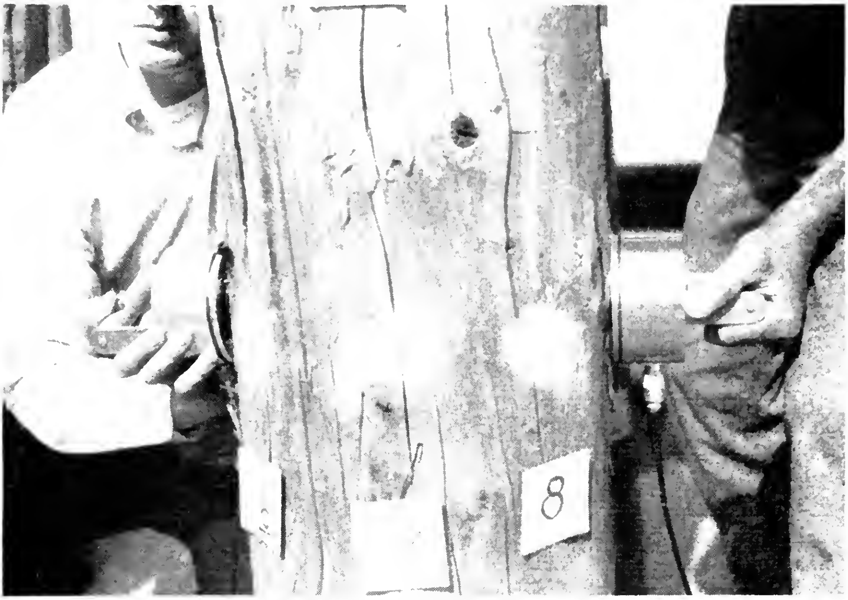
Power supply is 110 v, a-c, supplied by a generator or a 12-v inverter.

The transmitting head and the receiving head each contain a piezoelectric crystal (rochelle salt) on which is impressed a 25-kc sound wave. To insure intimate contact between the face of the heads and the timber surface, the two heads have an oil chamber and a rubber facing, but in addition they are coated with a mixture of sodium carboxyl cellulose and water (similar to gravy thickener) prior to each reading.

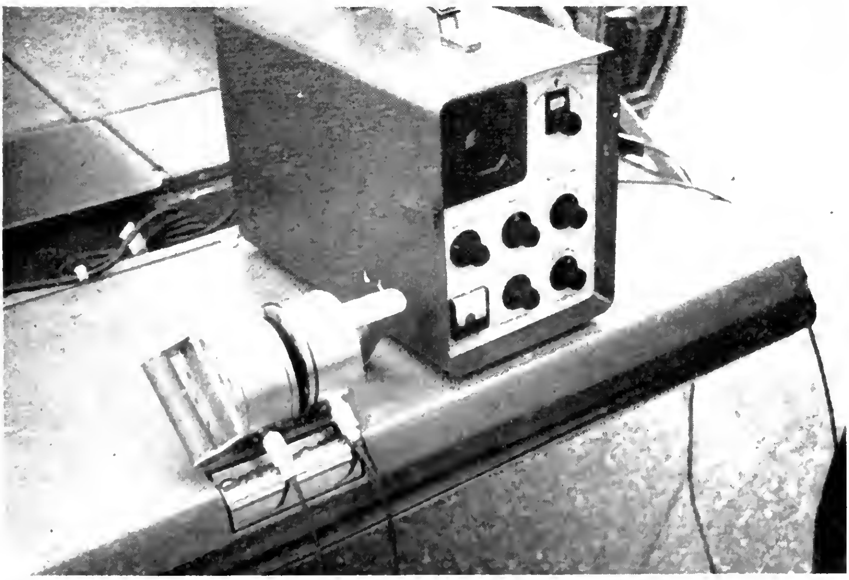
Before any readings are taken, the two heads are pressed together and a "transducer delay" reading is made. This is the base to which all subsequent readings

* Abstract of AAR Research Department Report No. ER-75. Copies of the complete report may be obtained at a nominal cost from G. M. Magee, director of engineering research, AAR Research Center, 3140 S. Federal St., Chicago, Ill. 60616.

Fig. 1—Device "A"

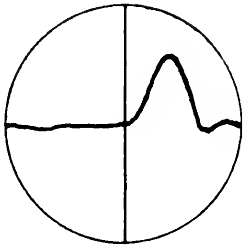


Transmitting and receiving heads in position for recording.



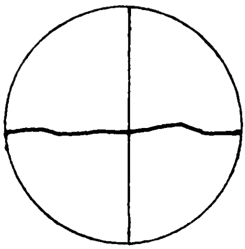
Control console and transmitting and receiving heads.

are referred. Then, with the two heads held firmly against the timber, and approximately opposite each other, a trace is recorded on the oscilloscope screen. By advancing the time knob, the trace is moved to the left until a definite increase in slope is noted. The point at which the slope increases is positioned under the vertical grid line and the time dial read. This is recorded as the "gross reading."



The portion of the trace to the left represents the transmitted wave and the portion to the right is the received wave.

In addition to recording the time interval, it is also necessary to note the amount of amplitude of the received wave, as this also is indicative of the soundness of the piece. Thus, poor amplitude indicates a void or decayed wood and coupled with high time readings, is evidence of considerable decay or large void. Fair amplitude, good amplitude and high amplitude are qualifying terms necessary to record for arriving at a decision regarding the internal condition.

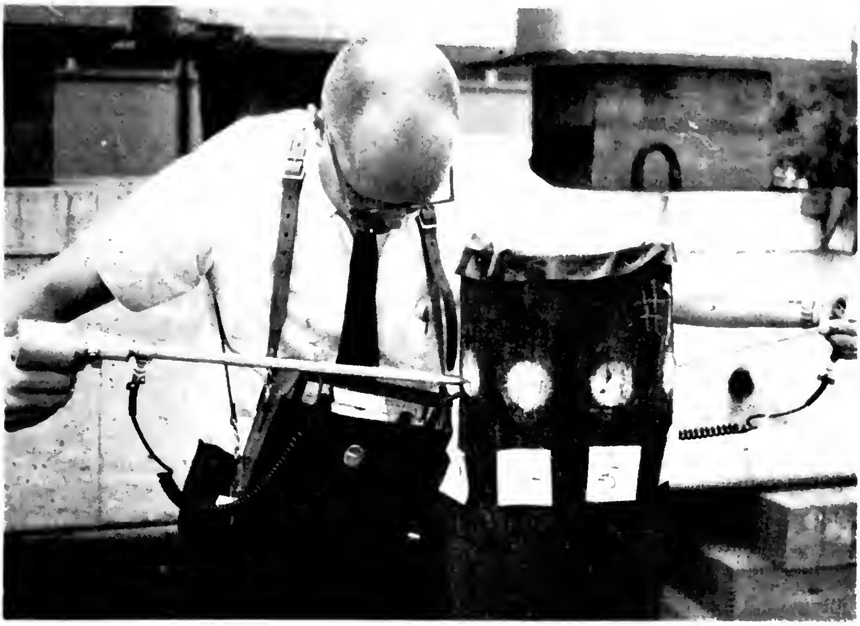


Since the signal is being sent and received continuously, the only time required to take a reading is that to locate the trace under the grid. This was generally only a few seconds for the experienced operator. Having recorded the time required for the sound wave to pass through the piece, it is also necessary to record the thickness of the piece. Using these two values, the pulse velocity is computed. This velocity, together with the amplitude of the trace, permit an evaluation of the internal condition. The use of this device requires three men—one each at the transmitting and receiving heads and one at the console.

Device "B"

Device "B" consists of a control box and two probes, one for transmitting and the other for receiving (see Fig. 2). The control box, weighing about 6 lb, can be carried by hand or shoulder straps. It contains solid-state circuitry and a milliammeter. It operates on rechargeable batteries. The transmitting probe contains a pistol-grip, self-triggering impact hammer. Near the tip of this probe is a piezoelectric crystal. An impact on the pole produces simultaneous electrical and sound

Fig. 2—Device "B"



Above—Control box and propes in use during recording.

Right—Close-up view of control box.

impulses which are transmitted to the control box and through the piece of timber. The receiving probe also contains a piezoelectric crystal which, on receiving the sound impulse, generates an electrical signal to terminate the time-interval measurement.

A short piece of wood is furnished with the instrument. It is used for calibration purposes. With the instrument ready for use, the operator positions the two probes approximately opposite each other on the piece of wood, applies slight pressure to embed the tip into the wood and triggers the hammer. A reading appears on the meter dial. The reading is compared with predetermined readings for sound wood of similar thickness (referred to as a "minimum" reading) and is an indication of the internal condition of the piece. High meter readings or readings close to that for sound wood indicate the piece being evaluated is also sound. Low readings indicate the presence of a void or decay. This device can be operated by one man. The probes are of sufficient length so that readings on a pile can be taken below ground by inserting the probes at an angle through the soil.

C. DESCRIPTION OF SPECIMENS AND TEST PROCEDURE

The specimens used consisted of short lengths of piles, caps and stringers supplied by railroads and which had been removed from service on account of internal decay. A few new specimens on hand at the laboratory were also tested. Most of the specimens were treated but a few were untreated. The species were not identified.

Typical specimens are shown on Figs. 3 to 8, incl. Also shown are the locations at which the instrument readings were taken. Four readings were taken at each section. The reading locations were marked on the specimen so that identical positions were obtained for each device.

The testing of Device "A" began on June 3, 1966, but because of heavy rain, only a few readings were taken and the test was completed on June 6, 1966. The wet weather was not considered to affect the instrument readings, but was not beneficial to the general conduct of the test.

Device "B" was demonstrated on August 31, 1966.

Manufacturer's representatives of both devices were present to operate their respective instruments and explain their use.

Moisture content at various locations was obtained at 1¼-in depth by use of a Delmhorst moisture meter.

The specimens were cut at the sections where the readings were taken and photographed for visual comparison with the readings. Typical photographs are shown in Figs. 3 to 8, inclusive. Photographs of all the specimens are included in Report No. ER-75.

D. GENERAL COMMENTS ON TEST RESULTS

The readings which were taken as well as the evaluations by the manufacturers' representatives are included in Report No. ER-75, but not in this abstract. Following are general comments regarding each of the specimens tested.

Pile No. 1: An inspection of the cut surfaces revealed no decay; however, both devices indicated that some was present (see Fig. 3).

Pile No. 2: No decay was present at the cut sections, but both devices indicated some decay.

Pile No. 3: Both devices revealed the presence of a small decayed center. Device "B" was quite definite on this.

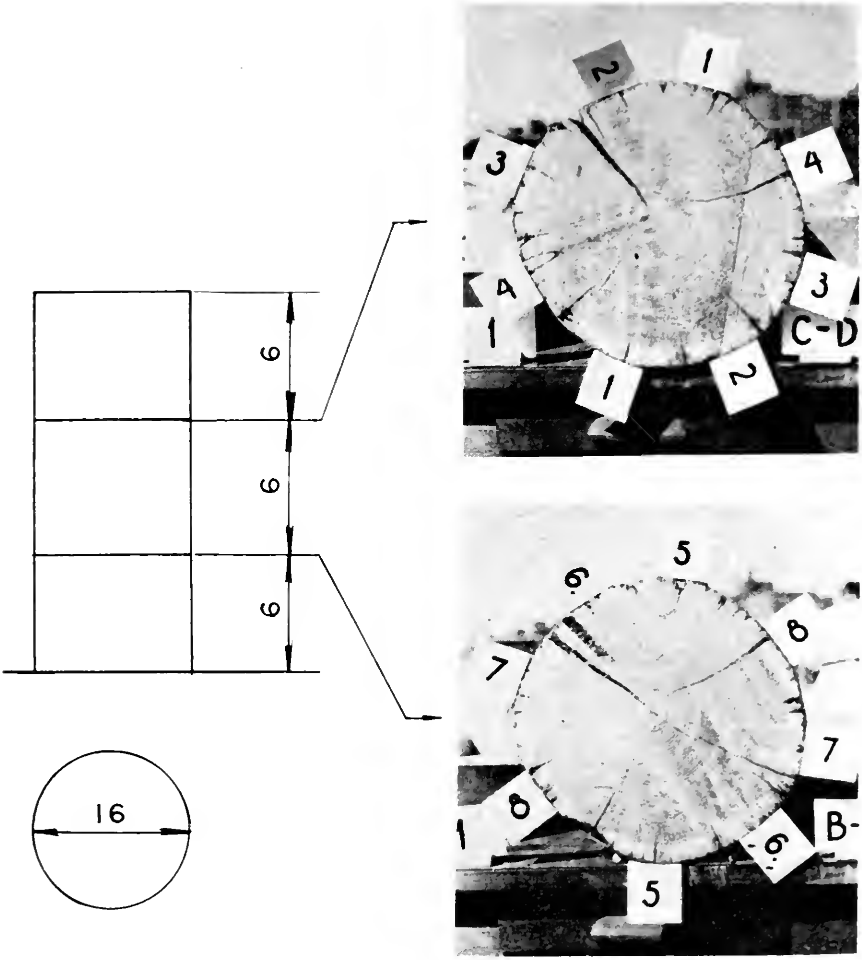


Fig. 3—Pile No. 1.

Pile No. 4: This pole had a large void and considerable decay. Both devices indicated this condition.

Pile No. 5: This pile had a large void, but there was also spongy wood present. Device "A" referred to this "soft wood." Device "B" indicated the off-centeredness of the void. Both devices gave good indication of the internal condition.

Pile No. 6: Both devices indicated the presence of decay throughout the piece. Device "A" indicated some sound wood at a few locations, but this is not shown on the photographs (see Fig. 4). Device "B" indicated more deterioration at 1–4 than elsewhere, but the photos do not show this.

Pile No. 7: This was a solid piece with no decay present. Device "B" indicated no decay, but Device "A" showed some soft wood present.

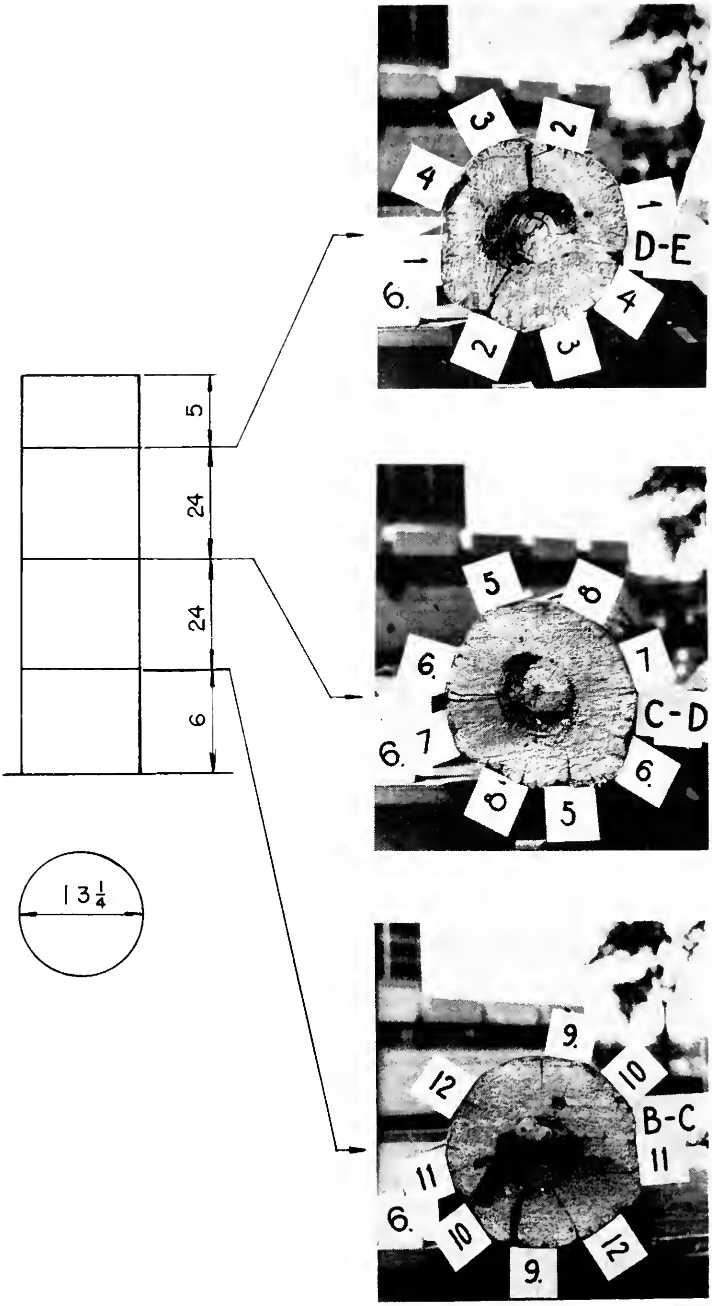


Fig. 4—Pile No. 6.

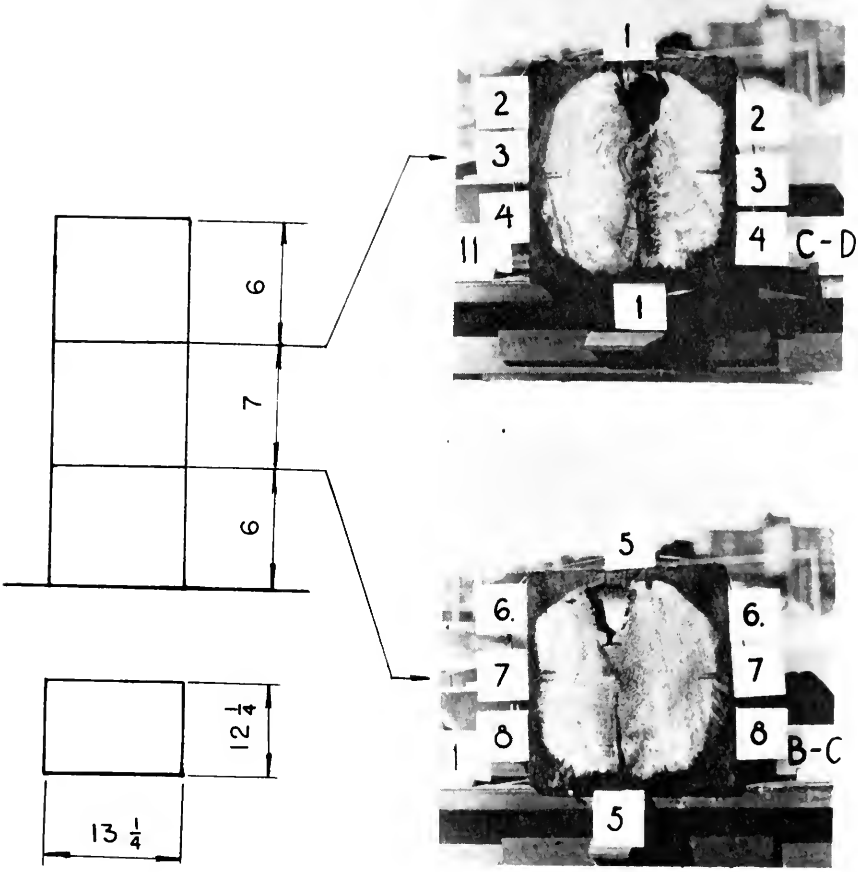


Fig. 5—Cap No. 11.

Cap No. 11: Both devices gave good indication of the internal condition and even defined the location of the void at the 6–6 location (see Fig. 5).

Cap No. 12: Same as No. 11. Both devices defined the decay area.

Cap No. 13: This piece had soft, spongy wood around the heart center though the photos show no void. Both devices indicated the presence of this (see Fig. 6).

Stringer No. 21: Both devices indicated decay sections. Both devices also showed solid wood.

Stringer No. 22: Both devices correctly defined the decay areas.

Stringer No. 23: This specimen had a small pocket of decay and some large checks, otherwise the piece was solid. Both devices indicated the presence of some decay, but neither was particularly definitive (see Fig. 7).

Stringer No. 24: Both devices indicated the presence of considerable decay, as shown on the photographs, as well as some solid wood at 2–2 and 6–6 (see Fig. 8).

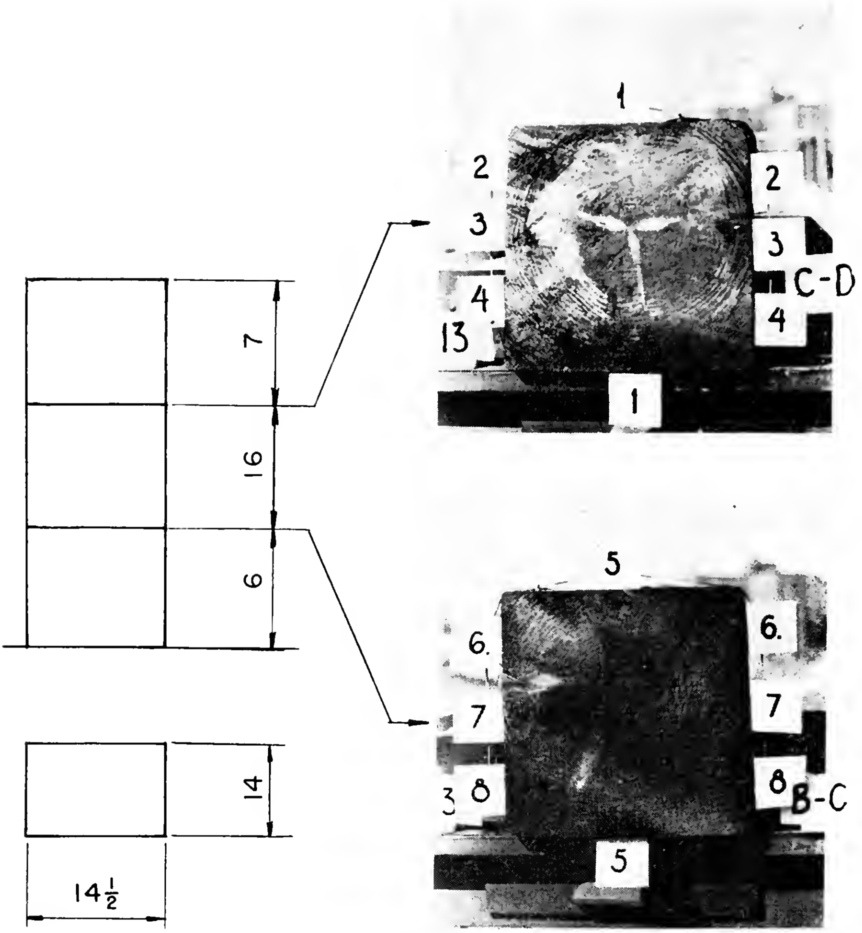


Fig. 6—Cap No. 13.

Stringer No. 25: Both devices indicated considerable decay throughout.

Stringer No. 26: Both devices indicated the condition of the specimen correctly.

In general, both devices gave a fairly good indication as to whether or not decay was present. Neither one, however, could indicate the size of the internal void nor did the manufacturers make any claims in this regard. Moisture in the wood or on the surface had no apparent effect on the instrument readings.

F. ACKNOWLEDGEMENTS

Some of the timber used for the evaluation of these devices was furnished by the Illinois Central Railroad and the Chicago & North Western Railroad. The two devices used were the property of the James Electronics, Inc., Chicago, and the Chapman Chemical Company, St. Paul Park, Minn.

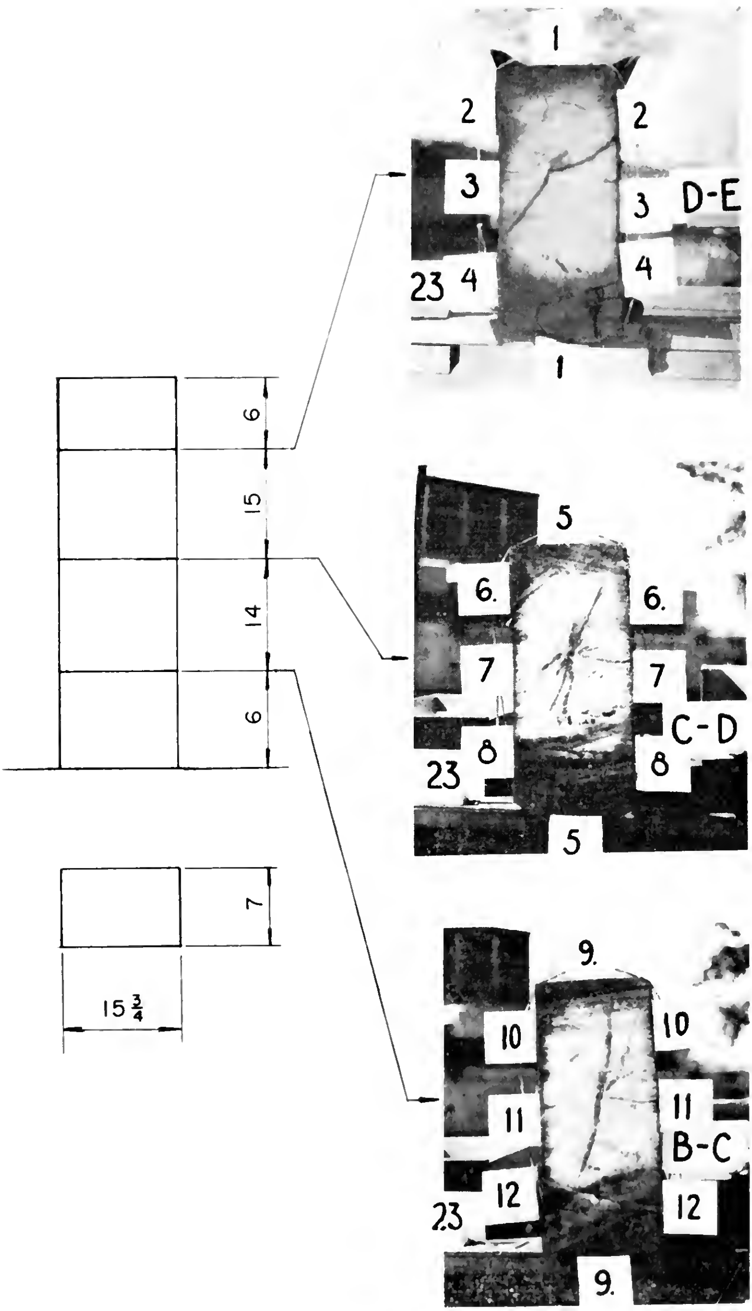


Fig. 7—Stringer No. 23.

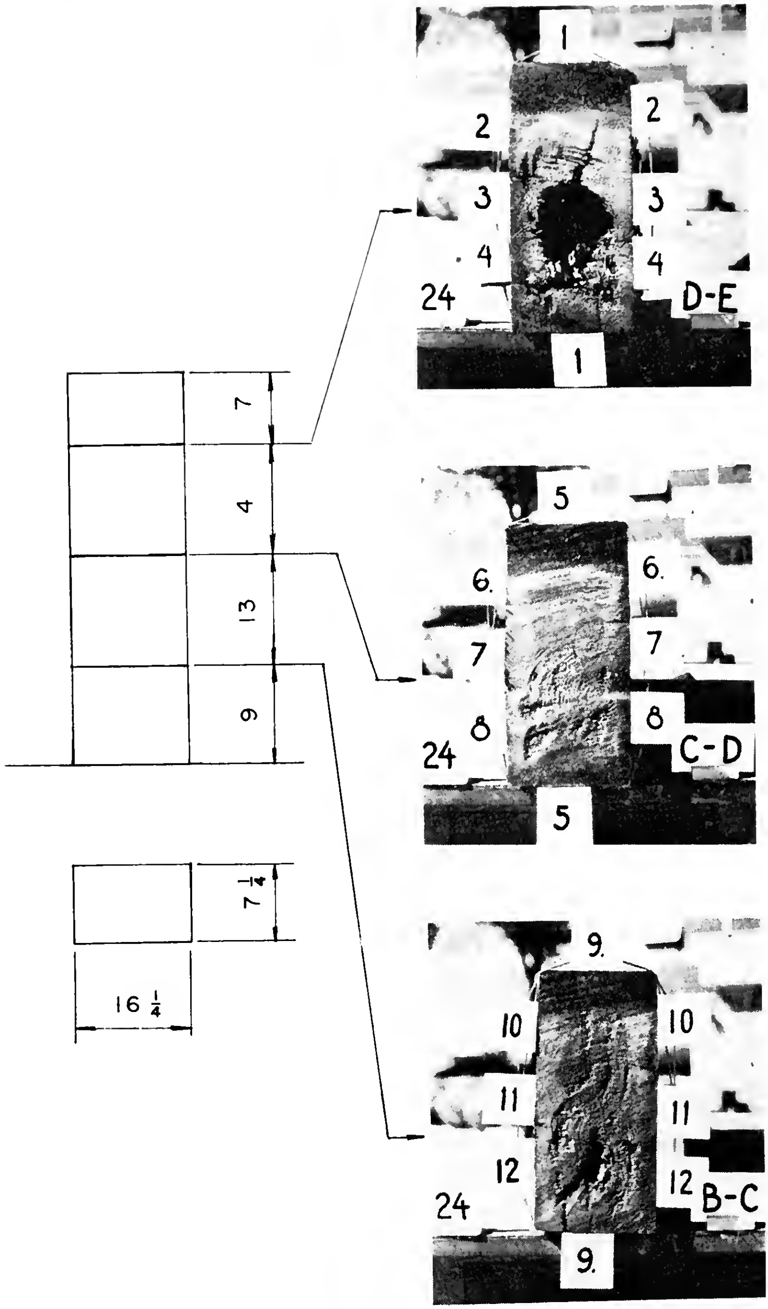


Fig. 8—Stringer No. 24.

Role of the Railroad Civil Engineer*

By B. F. BIAGGINI

President, Southern Pacific Company

Mr. Biaggini

One of the perogatives of my position which I hold very close to my heart is the right to attend and be a part of such meetings as this. My first job on the railroad was as a rodman, and the first 15 years of my life as a railroader was in the engineering part of the business. I can truthfully say that your profession and the engineering and construction projects you carry out are of great interest to me.

Beyond that fact, the entire business of one which is uniquely dependent upon the skills and abilities of the engineer, and the history of the industry illustrates this fact well.

Certainly my own company, Southern Pacific, is a fine example. The very beginning of this company, its original reason for existence, was dictated largely by the geography of the time—geography which could be thwarted only by one of the brilliant engineering feats of all time.

When Theodore Judah headed eastward from Sacramento and over the Sierra Nevada to seek a route for the Transcontinental Railroad, he was writing the beginning of one of the most dramatic chapters in the history of engineering. The magnitude of the task he faced, and the obstacles overcome by the men who completed his task, were so great, that it is difficult even today to comprehend how they could have been so successful.

This was, of course, a golden age for railroad engineers. These were the days that the pairs of steel rails were snaking across the country, binding cities together across hundreds of miles, and revamping the nation's economic and social life. For we must remember, too, how singular a position the railroad filled in the last half of the nineteenth century. It was the only practical means for long-distance travel, and its coming wrought great changes upon the face of the land.

Perhaps it was because of the dramatic growth and excitement of this time of furious construction that the railroad engineer gained the status and the glamor that he enjoyed. It was natural that, with the entire nation dependent for its transportation upon his abilities, he would be highly honored.

This was he situation throughout the remainder of the nineteenth century, and the first twenty years of the twentieth. Then, as the truck, the automobile and the airplane came into being, it was equally natural that attention would focus on them and the men who built the highways and waterways, with a corresponding decline in the stature accorded the railroad engineer.

But if you think this situation still exists today, you couldn't be more wrong. For the railroads, entering into a new era of advance technology and daring innovation are undertaking projects and making demands upon their engineers which rival and surpass the roughest tasks they faced when they started to build this railroad system.

* Remarks by Mr. B. F. Biaggini at the First AREA Regional Meeting, Portland, Ore., October 13, 1965.

For that matter, the glamor and excitement of the fight against nature which dramatized the early railroad engineer is still very much with us. My company today is completing the engineering on our Colton–Palmdale by-pass, a 78-mile line of new construction, which traverses some of California's most rugged area, in order to provide a short-cut around the congested Los Angeles basin for rail traffic moving between the West Coast on one hand and the Southwest and South on the other.

Nor must the civil engineer of today bow in humility when the old-timer tells him how rough it was in the good old days, as he made his way across the trackless wastes in the face of the elements. You heard Mr. Guerin [chief engineer, Great Northern] this morning tell you of the restoration work needed on his railroad after the great floods of last winter. This afternoon, Charley Neal, vice president and general manager of our subsidiary, the Northwestern Pacific, will show you and tell you of the tremendous fight he waged to get that railroad back into operation.

The catastrophes that struck both these railroads were conquered by the same dedication to duty, the same type of hard work, and the same disregard of personal risk and comfort which did so much to glamorize the old engineer.

And, speaking from my own experience, I can truthfully say that the 17 days that I spent on the summit of the Cascades last December and January, as we struggled to get Southern Pacific's main line back into service after that same catastrophic storm, were not the most tranquil I have ever experienced in my career as an engineer.

Despite these examples, there still can be no doubt that the role of the railroad civil engineer has changed mightily in the years since his first preoccupation was building the railroad. And yet, I reaffirm that the challenges he faces today are the most exciting, the most stimulating tasks which men of this profession have ever had presented to them.

It is, perhaps, to you younger engineers who have not been exposed to the mystique of "the good old days," that I should now address my words, for certainly you railroad civil engineers who have been long in this profession are tremendously aware of the changes that have taken place in our industry—and in your methods—in recent years.

Look, for example, at the revolutionary changes that have taken place in the railroad system that you now must engineer for. New, heavier diesel locomotives, mechanized maintenance of way equipment, Centralized Traffic Control, with its tremendous effect on the engineering of passing tracks; the new concepts in yards and their operations; a hundred and one other technical innovations, each of which has had direct and tremendous impact on your work.

Take, for instance, the use of Centralized Traffic Control, which we are installing throughout a great part of our system. This system of electronic control of trains has necessitated the re-evaluation of our entire system of passing tracks. We have moved them out of towns, lengthened them, and spaced them so accurately that, in many cases, our train meets can be made on the run, without either train stopping.

Or look at the impact of such a fundamental thing as traffic rates. As you may know, Southern Pacific has pioneered in the concept of incentive rates; rates which reduce the unit cost to the shipper for heavier loads. And, as shippers take advantage of these rates, our loads grow heavier. As loads grow heavier, our equipment grows larger. And suddenly you find yourselves redesigning curves and tunnels, and passing tracks and especially yards for new equipment, twice as long as was used when the road was laid out, and twice as heavy.

Take, also, into consideration the tremendous impact that modernized methods of operation are having on your duties. Today, in the face of the tremendous competition of other forms of transportation, we realize fully that the only way that we can protect our commerce is to do a better job of moving this country's products than any other carrier can. This is a problem we are facing squarely. Today's freight trains move at express speeds, in heavily powered trains; their operations must be worked out so they have the minimum of delay at terminals or along their routes; their performance must be of a nature that will permit us to unreservedly guarantee the delivery of their contents at their terminals on time—and on time means spotted and ready to unload.

What challenges does that bring to you? It does, of course, reinforce the necessity that I mentioned earlier—yards and tracks which are capable of handling today's equipment under today's operating conditions.

But, equally important, it also demands of you that the construction and maintenance work you are doing must be programmed so ingeniously that you not delay the tremendously important schedules of these trains. You're not a highway engineer that can build a detour, and let the traffic bump over it for several months while you build your road—or better yet, select a new route and blissfully work on it while the traffic speeds by a mile away. You're not the dam builder that can build a coffer dam and leave half the river open while he works on the other half.

No—you're required to bring this railroad up to the new standards that we need, with the consequent replacement of structures, and the realignment of tracks and yards, without disrupting the flow of traffic over its lines.

This was a tremendous order back in the days when railroads were first built. But with the great growth in our operations, and with the huge increases in our traffic, it becomes a tremendous task.

I am happy to say that you engineers have responded to this challenge with an ingenuity and resourcefulness which is unparalleled.

For example, Charley Neal can tell you of the winning fight he is carrying on today, trying to get the Northwestern Pacific completely rehabilitated in time to face whatever the next winter may bring. He's doing it by running freight trains all night long, then occupying the roadbed with an army of men and motorized equipment during the daylight hours.

Another example of this is the ingenious method being used to inject lime into our roadbed subgrade. The discovery that lime was an excellent stabilizing agent came from highway engineers, who windrowed the lime into the native material with a grader, prior to applying the asphaltic or concrete surface.

The railroad, faced with the need of maintaining traffic, couldn't use this method. Instead, we evolved a machine which injects lime vertically between the ties, and then forces it under pressure into the subgrade. The method has been used only a short time, but preliminary results indicate it is a promising tool in roadbed stabilization.

In other cases, major reconstruction jobs are being carried out with a minimum of delays to traffic. Truss bridges that were built 50 or 60 years ago are now being replaced with prestressed concrete structures, and the work is so well programmed that the actual time from the time the old bridge is taken out of service and the new one is opened averages about 6 hours.

Similar records are being made as we change out long stretches of rail and replace it with welded rail, literally between trains. And renewal of ties on bridges has been adapted to a method by which we install completed panels of ties, prefabricated at roadside sites, rather than using the old method of replacing them by hand.

We've also seen you adopt new methods of track maintenance by using a variety of modern equipment. We are experimenting with mechanized tie tampers, equipped with pneumatic tires, so they can be wheeled on or off the track at virtually any location, permitting trains to roll on by without delay, and ending the long delays caused by moving to the nearest switch. The old fashioned track gang of 150 men has been replaced with streamlined crews of 15 to 20 men equipped with the latest mechanical equipment, which can do the same job much faster and with much higher standards of quality.

These are challenges of today's operations, and our railroad civil engineers are meeting them with skill and ingenuity. But let us turn to another problem which is already upon us—and which will be with us for all time to come, as long as there are railroads.

I refer to the tremendous task that you are already engaged in, and will be even more so in the future, of engineering the railroad so that it can operate efficiently and compatibly with the environment which surrounds it. It is a large task today—it will be almost a superhuman one in times to come.

We here on the West Coast are increasingly aware of the huge influx of population which has turned our towns into cities and our cities into megapolitan areas sprawling across hundreds of miles. In this tremendous growth, in these new patterns of population, we are encountering great problems.

How, for instance, do you expand your yards to take care of increases in traffic, when the whole weight of the city is already pressing against its boundaries? And how do you keep your traffic speeding from point to point as street after street is created and strung across your tracks, with the corresponding pressure for speed limits and complicated safety devices?

And above all, how do you plan, engineer and install these devices and these tremendously complicated and expensive structures, and at the same time hold down the cost of your railroad operation, so that you can remain competitive with your intermodal competitors?

For these expenditures, vital as they are, bring no return to the railroad. It is true that if you increase the size of a yard, you are contributing to the profitability of the company through the increased business the yard can handle. But the extra engineering, and the extra costs due to the pressure of metropolitan area upon your location are purely wasted dollars—dollars spent for costs which can bring you no return.

And it is most obvious that grade crossing structures, crossing protection, and other devices needed to protect our lines from the onslaught of motorists make no contribution, either. Their virtue is a negative one—they permit us only to operate more efficiently than if they did not exist.

We can approach this problem in one way—by using modern technology and efficient methods in our installations so that we keep cost as low and efficiency as high as possible.

For example, on Southern Pacific we have devised an electronic crossing protector known as the Grade Crossing Predictor. Through the new electronic knowledge we have, this predictor can measure the speed and distance of an oncoming train, and gage it so that the gates are lowered for the minimal time. It can also be set to handle switching movements, so that if a train enters the crossing area and stops, the gates will raise, and only lower when it starts again.

The virtue to the motorist in this is obvious. To us it has several values. It does away with the large number of controlled track circuits with their insulated joints. But more important, by the very fact that it provides minimum delay to the flow of automobile traffic, it may obviate the need for a far more expensive grade separation at the crossing.

I have mentioned these efforts in the context of holding costs down where there is no revenue to be gained from the installations. But certainly, these same efforts to hold cost down apply all across the railroad, in everything you design and build.

For, as I told the Engineering Division of your national association in Chicago two years ago, engineering is a tool of profit. The saleability of our transportation product—its speed, its reliability and its low cost—depends almost entirely on how well our engineers perform. And you, by using your skill and imagination to find new ways to do things cheaper and better, play a major role in determining what part of our gross revenues we can turn into net profit. And net profit, I have no need to remind you, is the fuel which makes this railroad go—the tool which provides us the means to operate our business.

To an engineer this is a particular challenge, for he faces not only the task of designing and building properly, but the equally important task of discerning the proper procedure for the proper place and time. Engineers, I fear, have a basically human and prideful fault—they want to do the best job possible. And, in this pride, they often over-engineer.

It isn't necessary, for instance, that every mile of railroad we own be converted to CTC. Nor is it necessary to build the best bridge we're capable of building across a creek, if a cheaper bridge will handle the job adequately.

This is a real challenge, and in an atmosphere where it is cultivated, real genius flourishes. For the engineer who can look at the situation, and then, without regard to the way it is done now, comes up with a new answer which does the job more efficiently and less expensively, is a valuable man indeed.

One of the characteristics of such engineers as these is their persistent suspicion of any procedure that has been going along in just about the same way for any considerable length of time. Quite often, the more hallowed a procedure has become, the greater possibility there is for improving it.

Finally, today, I must come back to the position of stature possessed by the railroad engineer today. I do so because I must point out to you that it is from your ranks that a great proportion of the executives of our industry come from.

We need, it is true, the engineer that blazes his way across the spaces, improving and relocating his railroad. We need the transitman and the rodman, and the men who design our trestles and our structures.

But, gentlemen, we do not need them for their technical knowledge alone. In the freedom they have had to make their decisions, in their constant evaluation and re-evaluation of procedures upon which our railroads depend, they form the finest pool of management talent in existence.

It is no accident that the railroad industry is officered by a great number of ex-engineers.

The young man who becomes a railroad engineer today is faced with as exciting a range of possibilities and opportunities that exist anywhere. And, in the exercise and growth of his talents as an engineer, he is thoroughly training himself for the day when he must make greater and harder decisions, but using the same criteria that he used when he was young—imagination, and resourcefulness and ingenuity.

This industry, gentlemen, cannot stand still. When we stop, we start to die. When we hesitate, we lose ground. We must move continually forward, with new procedures and new services, new efficiencies and new savings—an ever-renewing industry.

You are the men who can do this, because this is what you have always done. Challenge the situation as it exists, and improve upon it. Devise a better way of doing things, and a more efficient one. Remold the railroad continually into an ever finer transportation system.

Just as Theodore Judah revolutionized the economy of the west when he started those iron rails over the Sierra, you can continually revolutionize the economy of the nation, by offering to it the finest railroad transportation system man can devise.

The Challenge of Railroading*

By W. THOMAS RICE
President, Seaboard Coast Line Railroad

Mr. Rice

It is a home-coming for me to be with an AREA group. It was my privilege to be a member of two of the AREA's illustrous committees for many years, to attend many great Conventions in Chicago and to take part in those things that make an AREA Convention such a memorable occasion.

I hope you share with me a feeling that we are in one of the greatest industries of America, with opportunities unlimited. Our problems are probably just as pressing today as they were when our predecessors built our railroads through the country's swamps, plains and mountains. The problems are different now, but they are certainly just as pressing; the challenge of railroading today is just as great as it was then.

It is inspirational to think just a little about what we have accomplished in the 130 or 140 years of existence of the American railroads under the private enterprise system. You and I can take great pride in the fact that our railroad system is the only one on the face of the earth that is still in the hands of private management, with the exception of one road in Canada, and the only one in the world where the taxpayer does not have to make up any deficit in railroad operations. It is the philosophy of private enterprise that built America and made this country the greatest producer of any land on the face of God's green earth. It behooves you and me and everybody else in the railroad engineering fraternity to adhere to that philosophy.

Some people are still saying that we should nationalize the railroads. Some of the surveys which have been conducted among high school students recently are just shocking; they show the philosophy of the high school graduate to be that the Government should provide jobs and that the Government should own public transportation and the banking and steel industries. Socialism creeps in so rapidly, but so unassumingly, that many of our most conscientious and well meaning citizens subscribe to that doctrine unknowingly.

Look at the records of our railroads during the two great wars. In World War I the government took over the railroads and it cost the taxpayers of America two million dollars a day to pay the deficit. In World War II, under private ownership, the railroads paid the various municipalities and states in which they operated, and the Federal Government, three million dollars a day in taxes, a saving of five million dollars a day to the taxpayers of our country, and they did a much better job.

They tell me that in Europe and the United Kingdom the railroads only take in 80 cents for every dollar they spend. And people tell me, and I'm sure they tell you, about the fine trains they rode in France, Germany and Switzerland, the wonderful meals they had and how well the track rode. What they don't know is that

* Speech given by Mr. W. Thomas Rice (then president, Atlantic Coast Line Railroad) at the Second AREA Regional Meeting, Hotel Robert Meyer, Jacksonville, Fla., October 7, 1966.

the taxpayer of these countries has to make up the 20-cent difference between what their railroads take in and what they spend.

Look at what we are doing with the private enterprise system in this country in every state in which we operate. For example, just within the last two weeks the ACL had a request from a county asking us to pay our tax bill. Actually, the tax bill is not due until the end of the year, but they wanted us to pay them cash now in order to permit them to meet their current cash requirements. I said to the gentlemen who brought in the request, "Do you realize that you are asking us to advance money on which we could get at least 5½ percent interest?" They had not thought about that, but the point of it is, we are so necessary as private enterprise to many of the communities through which we operate that even today, in this period of record prosperity, they are coming to us and asking us to pay our taxes well ahead of the due date so they will have money to operate on. How many people on the street know this? Very few, unless you and I tell them.

Think of what we mean to the national defense effort. You gentlemen who were working here in the Southeast back in October 1962 during the Cuban crisis will remember that the Defense Department tried almost to bury Florida and south Georgia under tanks, guns and other implements of war. The railroads suddenly became very important. The Defense Department had forgotten about the railroads for a long time but they sure knew where we were when things happened down in Cuba.

Getting on to some of the thrilling things that are going on in our industry: We are tailoring equipment to fit the needs of the shippers and you know what that has done to bring traffic back to the railroads. I know that many of you are concerned about what the new equipment is doing to the track structure, as I am. But as you go through most any yard today and look at the strings of new automobile cars sitting on the tracks, think where we were ten years ago. We didn't haul many automobiles then—we had lost this traffic practically in its entirety.

Look what we are doing with data processing equipment, and we are going to be able to use it to an even greater advantage if we can ever coordinate the efforts of the various railroads. It is sort of stupid that we are all spending money on this equipment. We are all trying to get the best and be there first, but we are not coordinating our efforts. At the last meeting of the Board of Directors of the Association of American Railroads, I think we faced up to that fact and we appointed a committee to get started on trying to coordinate the data processing systems of the American railroads.

Data processing by the railroads is highly regarded by our shippers. If they want to know where their traffic is, we can tell them. It means so much in per diem savings and increased car utilization if you know where each car is. If a car is lost, you might just as well not have it. Frequently, the lack of proper distribution methods is a result of lack of information.

I should talk a little bit about mergers. I think you gentlemen probably know as much about ours as I do. It has been a long-drawn-out affair. Tom Hutcheson and his great company (Seaboard Air Line) and ours have been trying to get together for a long time. We think we are probably in the last mile and certainly within the first half of 1967 we should get the final answer.* We are quite enthused about the potential of the proposed new railroad system and we sincerely believe the Supreme Court decision will be favorable.

* The merger was consummated July 1, 1967.

Now let's talk about something that happened just yesterday, and which I think was quite an achievement in that it kept something from happening that would have hurt us. The new hours-of-service law that was before the Congress was voted down. The new law would have cut the hours of service from 16 to 12 and would have had a great effect on our local freight operations, yard operations and mine runs. It was purely a labor-inspired law promoted under the guise of safety. The fact that the unions themselves were so divided on the bill indicates that it could not have been safety they had in mind. The Brotherhood of Locomotive Engineers actively opposed it. The Brotherhood of Railroad Trainmen and the Order of Railway Conductors took no position, but the Brotherhood of Locomotive Firemen and Enginemen definitely wanted it. The bill before Congress is dead for this session and it will have to be reintroduced in another Congress. Dave Hastings and a number of other operating vice presidents have been testifying against it. Apparently they did a pretty good job because we can forget it for this year. As you well know, the shortage of men would have made a reduction in hours of service most punitive to the railroads.

I should like to pay tribute to you men—and I include you supplymen—for the innovations you have made in track maintenance in the last 10 years; maybe I should say the last 15 years. The old days of the small section gang every few miles of track, and occasionally a floating gang with an air compressor and tools, and their methods of doing things by hand, have passed. If we hadn't found ways of doing track work mechanically, I just don't know where we would be today. You have been successful in practically offsetting the increased cost that we have been faced with in materials and labor in track maintenance. Your ability to fix up the track on a cycle basis, to clean ditches, lower the right-of-way to permit us to handle big trains with high-level loads under bridges, and to do many other maintenance tasks by modern machine methods is nothing short of phenomenal. I often wonder what the old Irish track foremen of the early 30's, when I first started railroading would think if he could see one of the maintenance gangs of today and compare its mechanized operations with the way he had to do this work. He often had about a half-dozen men digging in the ties in the summer and then trying to get them all tamped up before cold weather came.

Yes, we have gone a long way in reducing track maintenance costs, and at the same time we have made great progress in our ability to render transportation service. The big cars, the big locomotives, mechanization of our yards, proper communications and better operations have enabled us, from 1958 to date, to reduce the average revenue per net-ton-mile by 14 percent. Isn't that amazing. During the same time, the cost of labor has gone up 30 percent and the consumer price index has gone up about 13 percent. Find any other industry in this country that can match what we have done. Now we didn't reduce our tariffs each time just because we wanted to. We did it to meet competition. But we found ways and means of doing it that would still leave a little profit; by the volume method we were able to make enough money to pay our expenses and still have a few cents left over for our treasurer.

I think you as engineers have a great opportunity. You have the advantages of a good education and if you didn't have good minds you would never have been able to get your education. Frankly, your good minds are a great asset to the railroads, and not only in your engineering effort. Many of you will get into, or have already gone into, transportation work, and some of you now in transportation work will go back to engineering. I heard a comment made one day by a yardmaster, who probably had never finished high school, abont a superintendent who was made a high-ranking engineering officer. He said this man had been a superintendent long enough to make a good engineer. You know, there is a lot of sense in that remark. Appreciation of transportation problems is important. After all, transportation is what we render, and I appeal to you gentlemen to keep up the positive thinking, the new-innovation thinking, that has been so indicative of railroad engineering personnel for the last 15 years. To see how things are done today with machinery compared with how we did it 20 years ago is simply fantastic. We in management must find the money to buy the equipment, and I know you'd like to buy a lot of it. It is not always easy to do, but it is a great challenge. There is no limit to where we can go.

We must attempt to satisfy our shippers. The ordering and cleaning of equipment are great problems, and you can render a great service as you inspect your properties by keeping your eyes open for standing equipment. One of these big box cars costs $17,000, and if it is standing still it is just as much of a "deadbeat" to your company as a $17,000 piece of machinery that won't run because you don't have a part to repair it. And you know how upsetting it is when you buy a piece of expensive machinery and it breaks down. The same thing happens to our car distribution system. Sometimes it breaks down. So, when you see any idle equipment please remember that it is definitely a liability.

Speaking of new equipment: There are certain people in the traffic business of our railroads who are very zealous, and I admire them exceedingly—but they just don't realize what is involved when they say we can operate a 315,000-lb car on two 4-wheel trucks. I don't believe they realize what such cars are doing to our bridges and our rails. But who is going to tell them? If they haven't had some training in maintenance of way and structures, naturally they wouldn't know. The industrial traffic managers are just as zealous, and if they find one railroad that says it will operate such a car they think all roads can. It makes no difference to them what stresses the wheels put in the rails. That puts our traffic men behind the "eight ball," and I appeal to you gentlemen to explain to them what 79,000-lb axle loads do to our bridges and our rail. Go to your management and explain the matter to them also. No enlightened management wants to see their railroad torn up. I'm greatly concerned, because if one line says, "We will haul these heavy loads," and then another for competitive reasons says, "Yes, we will also haul them," the first thing you know the big cars will be running all over the country and they are getting bigger all the time. It is very serious thing. We find it particularly so here in the Southeast because we have a lot of branch lines with light rail. The point I'm making is that you gentlemen are best qualified to talk about these things with your management. Good management wants to know the facts. They don't want you to tell them anything just because you think it is what they want to hear. Even if the news is bad, they had better know it now than later on.

Getting back to the opportunities for engineers in railroading: There has been a scarcity of engineers in recent years. Many have come into railroading but haven't stayed. I think it is unfortunate that we can't make railroading attractive to them, that we can't in some way make them feel the challenge that is definitely there. We have lost too many good young men. Railroading doesn't seem to have glamour any more compared to some of the "astronautical" type of industries. It is sort of like being in the air force during the war; if you were a flyer you were doing something real romantic. I know that our wage structure has not been condusive to many young men, but the main thing is, we have gotten a bad name. If any of you fellows hunt birds you know that when a bird dog gets a bad name you might just as well shoot it. It is up to us to show the young technical graduates, and often their professors, that railroading is as thrilling a field as they can possibly go into. I think that anybody in the railroad business who can't feel any thrill in it should get out of it. But most of us do feel it, and we ought to be able to transmit that thrill to some of the younger generation and make them understand that we have great opportunities for them, particularly for the young engineer because he can rise to management in every type of operation. Certainly engineering graduates have made great contributions to the railroad industry in your and my lifetime. I am thrilled about railroading. It is a great industry and the American public is beginning to realize that it is an industry that is going forward and is not stagnant. We are not a decadent industry; we shall never be. You and I should drive any such feelings out of people's minds.

Advance Report of Committee 16—Economics of Railway Location and Operation

Report on Assignment 2

Engineering Methods and Economic Considerations Involved in Improving the Quality of Transportation Service

W. J. Dixon *(chairman, subcommittee)*, J. W. Barriger, K. W. Bradley, D. E. Brunn, P. J. Claffey, L. A. Durham, Jr., A. J. Gellman, T. D. Kern, H. N. Laden, J. C. Martin, R. W. McKnight, J. F. Partridge, W. L. Paul, J. S. Reed, L. K. Sillcox, J. E. Teal, J. R. Wilmot.

The Potential for Improvement in Freight Car Utilization

By J. R. WILMOT
Staff Engineer, Coverdale & Colpitts

The availability and expeditious movement of freight cars are without question fundamental concepts of railroad service.

Availability has been of perennial concern, and in its Annual Report for 1966 the Interstate Commerce Commission said, "Fiscal year 1966 was marked by the severest and most prolonged freight car shortages in the nation's history." The problem has obviously not been solved by accelerated depreciation, investment tax credits, or other incentives for increasing car ownership.

That improved utilization of cars is an effective supplement to, or partial substitute for, car purchases has received increasing recognition, and Daniel P. Loomis, then president of the Association of American Railroads, said in 1966 that more intensive car use is urgent and is perhaps the greatest single challenge facing United States railroad management.

This report examines the potential for increased car utilization by measuring in several terms the changes in American car utilization over a 50-year period and by comparing its current level with those of several foreign railroad systems. To that end, this report contains two analytical statements and accompanying text concerning car loading, four analytical statements and text concerning car movement, and a seventh statement containing various supplemental data supporting references in the text. In the analytical statements the source for the foreign statistics (and to a limited degree, those for the United States) is the publication "International Railway Statistics," compiled by the International Union of Railways (UIC) in Paris.

CAR LOADING

On *Statement 1* there is shown the 50-year historical trend of the utilization of car capacity in terms of average load on American railroads. The years 1914 and 1964 are shown to tie this statement to others in the report. From 1915 to 1955 the figures are shown at five-year intervals, and from 1955, annually.

An uninterrupted increase in car capacity is shown for the half century. The trend in average load has been, as would be expected, generally upward, but with irregularities. On an annual basis, the increase has been consistent beginning with 1959. The column of ratios, showing the percentage of the consistently increasing capacities which was utilized by the generally increasing loads, shows an erratic

Statement 1

Freight Car Capacities and Loads
Class I and II Line-Haul Railroads in the United States
Years 1914 to 1964

	Average Capacity Per Car (Tons)	Average Load Per Car(1) (Tons)	Ratio: Load to Capacity
1914*	39.1	21.1	.54
1915*	39.7	21.1	.53
1920	42.4	26.7	.63
1925	44.8	24.6	.55
1930	46.9	24.3	.52
1935	48.3	23.5	.49
1940	50.0	25.4	.51
1945	51.1	30.2	.59
1950	52.6	30.0	.57
1955	53.7	30.9	.58
1956	54.0	32.0	.59
1957	54.5	32.4	.59
1958	54.8	32.1	.59
1959	55.0	32.3	.59
1960	55.4	33.1	.60
1961	55.7	33.8	.61
1962	56.3	34.9	.62
1963	56.8	36.3	.64
1964	58.2	37.6	.65

(1) Calculated from revenue net ton-miles and total loaded car-miles.

* Year ended June 30.

Sources: Interstate Commerce Commission, "Statistics of Railways in the United States," 1914; "Transport Statistics in the United States," 1964.

pattern over the 50-year period for which the figures are shown at five-year intervals. The effects of war can be seen in 1920 and 1945 (high) and of depression in 1935 (low). The ratio levelled off for four years from 1956 to 1959, and has since been steadily climbing.

Given the economics of the railroad industry, there is no more attractive form of unit cost reduction than larger-capacity cars, if the capacity is utilized. The ratio of net-to-tare weight can be expected to be improved with larger cars loaded to the same percentage of capacity as smaller cars. For cars of the same size, the net-to-tare ratio is obviously increased with heavier loading.

Filling the larger cars is, however, a commercial matter. As long as the average box car has a larger capacity and a higher minimum weight requirement than the average van trailer, there will be some shippers who will use trucks because they work with small volume and low inventories. Their reasons may be minimizing capital requirements, limited storage space, or maintaining market flexibility. Some of the shippers will be willing to pay a premium on the freight rate for the privilege of shipping in smaller volume, and that factor has nothing to do with any other advantages they may find in truck service, such as faster transit time or store-door pickup and delivery. Minimum weights for rail carloads can be competitively reduced to the same level as for truckloads, but at the penalties of moving unneeded tare weight and investment in unused car capacity. Or, the traffic of shippers strongly oriented to small volume can be relinquished to the trucks. In either case, to encourage volumes on which railroad costs are more favorable, incentives are usually required in the form of rates that decrease per unit of weight as loading per car increases. From Statement 1 it appears that for about 45 years from 1915 American railroads were successful in realizing the cost advantages of larger cars by approximately maintaining over the period the same ratio of load to capacity in the larger cars as in the smaller cars that were gradually being replaced. Since 1960, however, the cost advantage has been compounded by an increase in the utilization of car capacity. This recent period generally coincides with the increasing introduction of incentive rates. Traditionally, the utilization of larger cars has been induced by making them subject to higher minimum weights and also in some cases by the publication of alternating rate and minimum-weight combinations. The more recent true incentive rates, however, encourage heavier loading in a particular car of a given size. The ratio column of Statement 1 suggests that these rates have been successful in that they apparently have had a clearly discernible influence on the overall car utilization of American railroads.

The favorable trend in utilization of car capacity might have occurred (without any real improvement for any specific commodity) if an increasing share of the traffic were in bulk commodities which are normally loaded much closer to car capacity than is the case with general freight. Such an increased share has not appeared, however. Bulk commodities (principally coal, ore, sand, gravel and crushed stone) now constitute about 50 percent of tons originated, and during the last decade the proportion has been decreasing at a rate of about 0.5 percentage point per year.

The increase in load-to-capacity ratio is the more impressive when it is recognized that it has taken place more or less concurrently with the widespread introduction of flat cars equipped with racks for carrying new automobiles on which the normal loading amounts to only a small fraction of weight capacity.

This analysis does not go into the matter of revenue concessions that have been made to induce heavier loading, but referring again to the cost economics of

Statement 2

Freight Car Capacities and Loads
United States and Foreign Railroads
Year 1964

	2	3	4	5	6
	Average Capacity Per Car(1) (Tons)	Average Load Per Car: Originations(2) (Tons)	Average Load Per Car: All Traffic(3) (Tons)	Ratios: Load to Capacity: Col. 3 to Col. 2	Ratios: Load to Capacity: Col. 4 to Col. 2
United States (4)	58.2	47.8	38.3	.82	.66
German Federal Ry.	27.1	19.4	14.7	.72	.54
Belgian National Ry. Co.	25.9	21.8	18.7	.84	.72
Danish State Rys. (5)	22.7	7.8	9.6	.34	.42
French National Ry. Co.	26.5	19.5	14.3	.74	.54
British Rys.	18.2	13.6	10.5	.75	.58
Italian State Rys.	24.0	13.1	11.6	.55	.48
Netherlands Rys.	29.2	17.9	16.3	.61	.56
Swedish State Rys. (6)	28.2	16.1	14.1	.57	.50
Swiss Federal Rys.	23.2	6.3	10.7	.27	.46
Japanese National Rys. (7)	18.3	17.3	15.4	.95	.84

All tons are tons of 2,000 lb.

(1) Excludes privately-owned cars, and for European systems, narrow-gage cars.
(2) Calculated from tons originated and cars originated, revenue traffic only.
(3) Calculated from net ton-miles and loaded car-miles, revenue and non-revenue traffic.
(4) Class I Line-Haul Railroads.
(5) Year ended March 31.
(6) Year ended June 30.
(7) Year ended March 31, 1965.

Sources: (United States) - Interstate Commerce Commission, "Transport Statistics in the United States," 1964, and Statement No. 66100, Freight Commodity Statistics, 1964.

(Other Countries) - International Union of Railways, "International Railway Statistics," 1964.

railroad car movement, the many expenses that do not vary with incremental weight leave a large area for profitable maneuvering.

Statement 2 gives a comparison for 1964 between the railroads of the United States and the principal national railroad systems of Western Europe and of the national systems of several smaller and prosperous Western European countries and Japan. It should be noted that the average load per car is shown on two bases: first, on traffic originated, and, second, on total traffic carried weighted by miles. The second basis is the one used on Statement 1. The differences between the two bases for the United States and presumably elsewhere are due simply to the fact that low-density freight tends to move longer distances than high-density freight.

It is immediately apparent that the capacity of the average American car is well more than twice that of cars in almost all the other countries. The columns showing average loads can be passed over to go on to the ratios (columns 5 and 6). Here, the American load-to-capacity ratios are higher, by either method of measurement and by substantial margins, than those of any of the other systems except those of Belgium and Japan. This relationship exists despite the much larger size of American cars, which in theory would make it more difficult to attain more nearly full loads.

The high load ratio in Belgium is probably explained by the large proportion of coal and ore traffic (see Statement 7-A). As will be shown on Statement 6, the average annual and daily mileages in Belgium are very low. For Japan, on the other hand, the average annual and daily mileages are by far the highest of any of the compared countries. When the highest mileages are coupled with the highest loading ratios (without the influence of a large proportion of coal and ore traffic), it can only be concluded that there is a different concept of car utilization in Japan than in other countries, or, conceivably, a non-standard basis for reporting statistics to the UIC. The low average capacity in Japan can be partially explained by the fact that it is for narrow-gage cars, whereas the European averages are for standard-gage cars. The apparent unusually high car utilization on all counts in Japan is not attained from advantages accruing from a lack of competition, because the Japanese National Railways, despite their good car performance, show up unfavorably in their share of total freight traffic carried by all modes (see Statement 7-B).

The lower load-to-capacity ratios in all the European countries, except Belgium, than in the United States can reasonably be attributed to differences in commercial, or rate, policy. As to the small size of the cars, there is nothing inherently inefficient in a policy of small cars if it is dictated by commercial considerations, such as those mentioned which cause some shippers in the United States to prefer shipping smaller volumes in truckloads than is possible in carloads. Probably the small cars in Europe reflect, in part, a generally smaller scale of business transactions than prevails in the United States. It is unlikely that there are serious technical considerations, i.e., clearance and weight restrictions, that would prevent widespread use in Europe of cars equivalent to the American 40-ft and 50-ton category. The hook-and-screw couplings generally used would, however, make freight train length a limiting factor at a lower tonnage level than in the United States.

In most countries except the United States and Canada freight rates are heavily dependent upon a simple system of classification and class rates, whereas here this basis exists for little more than small-volume and unusual shipments and as a set of principles which can sometimes contribute to setting the multitude of special rates under which most traffic actually moves.* The traditional class-rate system should, through the proper grading of incentives in the three interdependent elements of the system—the classification ratings, the rates for each class for varying distances, and the minimum carload weights for each commodity—produce optimum revenue per car on cars loaded to near capacity, either cubic or weight. To the extent that heavy loadings reflect optimum revenues, the generally class-based rate structures of Europe apparently are not attaining this end to the same degree as the flexible and complex rate structure of the United States. To what extent the lower load-to-

* Several years ago the French National Railways pioneered a highly cost-oriented system of freight rates. The most distinctive departures from tradition appear, however, to be in the geographical, or distance, aspects of the structure, rather than in the differentiations between commodities and between varying loads.

capacity ratios in Europe may be the result of a higher proportion of merchandise traffic that loads to cubic capacity before weight capacity is reached cannot be determined from available information. The percentage of coal and ore to total traffic in Great Britain, France and the Netherlands (see Statement 7-A) indicates that the inverse proportion traffic other than coal and ore) is not a factor, in those countries, at least.

Rate complexity, as it exists in the United States, is hardly a goal to be sought after, but with it comes the ability to refine rates to meet particular situations—geographically, or by commodity or length of haul or shipper requirements—and attain efficiencies in the utilization of car capacity that apparently are not being attained in other countries with simple and nationally uniform rate structures. Recent advances in the more sophisticated realization of the potential present in the American system of freight rates (as exemplified by incentive rates) together with developments under study to offset the complexity of the system by fully or partially automating the rate-publishing and rate-retrieval processes offer much promise.

CAR MOVEMENT

The prior section of this report dealt with car utilization in terms of average loads, which are influenced by the fixed capacities with which cars are built and the volumes with which shippers load them under the interplaying forces of customs in their trades and the railroad rate structure. These influences might be termed "passive," as opposed to the more "dynamic" influences of time and motion—as affected by train speed, time in terminals, time for loading and unloading, and the distribution of empties, to name the most important—to be analyzed in this section.

Statement 3 does not directly concern car utilization but has been prepared to show how several significant productivity factors of American railroads have increased in the half century from 1914 to 1964. While the number of trains operated over an average mile of road on an average day decreased by one-half, the units of traffic* per mile of road doubled, the net tons carried by the average freight train increased three times, and the productivity (in terms of traffic units) per employee increased almost five times.

Statement 4 comes directly to the matter of car utilization and its improvement in half a century.** Very broadly, the increase of 2.14 times in net-ton-miles with a decrease in car ownership of 34 percent, indicates an increase of 3.25 times in car productivity. This increase compares favorably with the increases in other productivity factors shown in Statement 3. It must be qualified, however, as explained in the notes on Statement 4, by the effect of the increase in the average size of cars. Productivity (in net-ton-miles per car) would have increased 1.65 times because of the higher average loading, with no improvement in movement and distribution. The resulting qualification of the previously cited increase of 3.25 times gives an increase of 1.97 times in car productivity that apparently is due to improved movement and distribution; that is, less idle time between loadings, higher train speeds, etc. This rate of improvement is less than that shown on Statement 3 for other significant areas of performance.

* The traffic unit (equal to one net-ton-mile or one passenger-mile) is a widely-used international measurement useful for comparing railroads with materially different mixes of freight and passenger traffic.

** Private car line ownership was not reported in 1914 and, therefore, privately owned cars are excluded for both 1914 and 1964. It is assumed that there was a significant number of those cars in 1914 as there was in 1964, and that their exclusion from the ownership figures in both years, while their mileages and the ton-miles of their lading in both years are included, will not materially affect the calculated averages and factors.

Statement 3

Selected Statistics and Averages
Class I Line-Haul Railroads in the United States
Years 1914 and 1964

	1914*	1964	Ratio: 1964 to 1914
Miles of Road	226,999	217,116	.96
Gross Ton-Miles, Trailing Load (Millions)	N.A.	1,557,624	N.A.
Net Ton-Miles, Revenue and Non-Revenue (Millions)	313,958	671,619	2.14
Passenger-Miles (Millions)	34,567	18,245	.53
Total Train-Miles (Thousands)	1,250,490	603,916	.48
Freight Train-Miles (Thousands)	590,834	414,470	.70
Employees	1,640,029	665,034	.41
Train-Miles Per Mile of Road Per Day	15.1	7.6	.50
Gross Ton-Miles Per Mile of Road (Thousands)	N.A.	7,174	N.A.
Traffic Units (1) Per Mile of Road (Thousands)	1,535	3,177	2.07
Net Ton-Miles Per Freight Train-Mile	531	1,620	3.05
Traffic Units (1) Per Employee (Thousands)	213	1,037	4.87
Operating Ratio (Percent)	72.05	78.50	

(1) Total traffic units are the sum of the total net ton-miles and total passenger-miles.
N.A. Not available..
* Year ended June 30.

Sources: Interstate Commerce Commission, "Statistics of Railways in the United States," 1914 (Supplemented by Bureau of Railway Economics, "Statistics of Railways of Class I, 1911-1922"); "Transport Statistics in the United States," 1964.

The increase of 1.97 times in car productivity due to improved movement and distribution has apparently been achieved in part at the expense of an increase in the ratio of empty-to-loaded car-miles. This unfavorable factor has increased 1.12 times.

Where Statement 3 shows a historical comparison of several performance factors for American railroads, *Statement 5* give a comparison of the same factors for 1964 between the railroads of the United States and the same foreign railroads whose car capacity and loading statistics were presented on Statement 2. The density factors indicate that American railroads are the lowest in terms of trains but fairly typical in terms of gross tons and traffic units. In net tons per freight train the American average is more than four times higher than the second-rank system. In productivity per employee the American railroads stand more than three times higher than the next highest system. The operating ratio of American railroads is

Statement 4

Freight Car Statistics
Class I Line-Haul Railroads in the United States
Years 1914 and 1964

	1914*	1964	Ratio: 1964 to 1914
Cars Owned	2,263,015	1,488,385	.66
Average Capacity (Tons)	39.1	58.2	1.49
Loaded Car-Miles (Thousands)	13,513,801	17,515,682	1.30
Percent Loaded of Total Car-Miles	67.8	60.6	.89
Net Ton-Miles, Revenue and Non-Revenue (Millions)	313,958	671,619	2.14
Net Ton-Miles Per Car	138,734	451,240	3.25
Average Load Per Car (Tons)	23.2	38.3	1.65

Net Ton-Miles Per Car Per Year has increased 3.25 times; however, Average Load has increased 1.65 times, so the improvement apparently due to more efficient movement and distribution has been 1.97 times.

At the same time, the Total Car-Miles (Loaded and Empty) required to produce one Loaded Car-Mile has increased 1.12 times (the reciprocal of .89), perhaps as a penalty in achieving the more efficient distribution.

There is no way to directly relate the expenses of increased Empty Car-Miles with car productivity factors. However, purely as a statistical exercise, if a simple arithmetic calculation is made, the apparent improvement of 1.97 times attributable to more efficient movement and distribution would be reduced to 1.76 times.

* Year ended June 30.

Sources: Same as for Statement 3.

by far the most favorable, but the comparison should be viewed with reservations. In some countries the nationalized railroads are intended to break even; for example, the Swiss Federal Railways, with an operating ratio of 91.33, reported a ratio of all charges to receipts of 98.7 against an ideal of 100.

Statement 6 compares American car utilization with that of the same foreign systems whose statistics are shown on Statement 5. This is the most significant statement of the four in the section on car movement. Some assumptions and estimates have necessarily been made. For the most part, they concern exceptions or small parts of the total, and there is no reason to believe that with complete and exact data the significant averages and factors would be materially different.

Statement 5

Selected Statistics and Averages
United States and Foreign Railroads
Year 1964

	Miles of Road	Gross Ton-Miles, Trailing Load (Millions)	Net Ton-Mile (1) (Millions)	Passenger-Miles (Millions)	Total Train-Miles (Thousands)	Freight Train-Miles (Thousands)	Employees	Train-Miles Per Mile of Road Per Day	Gross Ton-Miles Per Mile of Road (Thousands)	Traffic Units (2) Per Mile of Road (Thousands)	Net Ton-Miles Per Freight Train-Mile	Traffic Units (2) Per Employee (Thousands)	Operating Ratio (Percent)
United States (3)	a [illegible]17,116	1,557,604	6[illegible]9,457	18,257	598,130	414,682	665,034	7.[illegible]	7,174	3,170	1,616	1,035	78.50
Belgian National Rys. Corp.	2,[illegible]	20,977	4,866	5,008	50,993	13,679	62,012	46.[illegible]	7,049	3,326	356	159	95.67
British Rys.	15,[illegible]4	N.A.	17,[illegible]	19,862	345,912	101,430	39[illegible],[illegible]5	59.1	N.A.	2,363	177	95	112.58
Danish State Rys. (4)	1,[illegible]44	7,070	1,065	2,032	25,284	5,595	27,961	44.7	4,579	2,006	190	111	101.19
French National Rys. Corp.	[illegible]4,[illegible]	162,13[illegible]	47,015	23,479	280,566	137,383	360,161	31.[illegible]	6,731	2,926	342	196	103.73
German Federal Ry.	18,[illegible]	160,244	42,954	23,088	362,847	121,769	459,306	52.2	8,436	3,477	353	144	N.A.
Italian State Rys.	10,22[illegible]	60,626	10,655	17,342	160,181	40,598	191,369	42.8	5,929	2,738	262	146	101.21
Netherlands Rys.	2,[illegible]12	17,1[illegible]	[illegible],7[illegible]4	4,877	47,378	12,150	28,694	64.4	5,521	3,780	224	265	99.61
Swedish State Rys. (5)	8,121	27,031	7,678	3,206	71,852	24,527	56,905	24.2	3,329	1,340	313	191	103.14
Swiss Federal Rys.	1,822	19,133	3,345	5,283	51,371	16,743	42,190	77.3	10,501	4,735	200	205	91.33
Japanese National Rys. (6)	12,880	151,582	4[illegible],333	101,953	357,439	100,542	461,931	76.0	11,769	11,047	401	308	98.37

All tons are tons of 2,000 lb.

(1) Revenue and non-revenue service.
(2) Total traffic units are the sum of total net ton-miles and total passenger-miles.
(3) Class I Line-Haul Railroads.
(4) Year ended March 31.
(5) Year ended June 30.
(6) Year ended March 31, 1965.
N.A. Not available.
a See Source, below.

Source: International Union of Railways, "International Railway Statistics," 1964, except item noted (a) same as for Statement 4.

Statement 6

Freight Car Statistics
United States and Foreign Railroads
Year 1964

	[illegible] (1)	[illegible]	[illegible]	Average [illegible] Per Car Per Year	6 Average [illegible] Per Car (Days)	7 Average Haul Per Loaded Car (Miles)	Average Loaded Miles Per Car Per Year	Percent [illegible]	Percent of Cars [illegible]	Normal Free Time for Loading and [illegible] (Hours)	Effective Average Miles Per Day Per Car [illegible]
United States (4)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Belgian National Rys. [illegible]	[illegible]	[illegible]	2,[illegible],[illegible]41	[illegible]	1.1	[illegible]	2,[illegible]	[illegible]	[illegible]	24 [illegible]	10.[illegible]
British Rys.	[illegible]	[illegible]	[illegible]	[illegible]	1[illegible]	[illegible]	2,554	60.0 [illegible]	[illegible]	[illegible]4	14.5
Danish State Rys. (4	1[illegible]	[illegible]	[illegible]7[illegible],4[illegible]	5[illegible].1	6.4	11[illegible]	6,681	79.	[illegible]	24 A	3[illegible].5
French National Rys. [illegible]	[illegible]1.1	14.[illegible]	13.[illegible]	37.4	[illegible]	2[illegible]	8.228	77.[illegible]	[illegible]	[illegible]	[illegible]
German Federal Ry.	[illegible]4,84[illegible]	1[illegible]	1[illegible]	[illegible]	7.3	1[illegible]	7.9[illegible]	6[illegible]	[illegible]	[illegible]4	4[illegible]
Italian State Rys. (	134,14[illegible]	4,64[illegible]	[illegible],881.10[illegible]	[illegible]	12.[illegible]	1[illegible]	5.751	68.0	[illegible].0	[illegible]4 A	[illegible]0.[illegible]
Netherlands Rys.	[illegible]4,[illegible]1	1,[illegible]1[illegible].1[illegible]	1.5[illegible]2.[illegible]	[illegible]	5.[illegible]	8[illegible]	5.440	61.0	[illegible].1	24 A	[illegible]2.4
Swedish State Rys. [illegible]	53,93[illegible]	[illegible]	[illegible]34.4[illegible]	6[illegible]	6.1	163	9.78[illegible]	7[illegible]	1.[illegible]	[illegible]4 A	[illegible]
Swiss Federal Rys.	3[illegible],[illegible]1	3.[illegible]	[illegible].777.[illegible]7[illegible]	[illegible].4	[illegible].2	7[illegible]	5,441	[illegible]9.	1.4	24 A	[illegible].2
Japanese National Rys. (7	141,2[illegible]	1[illegible],[illegible]	11.[illegible]	9[illegible]	4.[illegible]	2[illegible]	16.72[illegible]	[illegible]	[illegible]	[illegible]	[illegible].4

Basic data cover revenue and non-revenue service, except as noted.

(1) For U.S., includes cars owned by private car lines reporting to I.C.C.; for other countries, includes private owned cars, and is adjusted for average daily balance (relatively small in all cases) of cars interchanged. For foreign countries, includes cars [illegible] connecting secondary systems.
(2) Class I Line-Haul Railroads.
(4) Year ended March 31.
([illegible] Narrow gauge [illegible] are excluded.
([illegible] Year ended June [illegible].
([illegible] Year ended March 31, [illegible].
([illegible] Arbitrary [illegible] [illegible]
[illegible] service [illegible]
N.A. Not [illegible]

[illegible] States [illegible] "[illegible] United States." [illegible] published [illegible]
[illegible] Commerce [illegible]

In calculating Average Loaded Miles per Car per Year (column 8, the product of column 5 times column 7), it was necessary to assume for the United States that the Average Haul (column 7), calculated from total loaded car-miles less estimated non-revenue car-miles and Loaded Cars Originated (column 4), is not greatly affected by differences between cars originated and cars terminated in Canada and Mexico and on short lines. For other countries, it was necessary to assume that the Average Haul (column 7), a reported figure applicable to total loaded cars handled, is also applicable to loaded cars originated.

For Normal Free Time for Loading and Unloading (before assessment of demurrage) (column 11), the normal hours in effect in Great Britain, France, Germany and Japan were obtained from the New York representatives of the railroads of those countries. On the basis of this information, 24 hours was used for the other European countries for which specific information was not obtained.

Average Turnaround per Car (column 6) is not of great significance in itself, because it obviously should be shorter for a system with a short average haul. For this reason, to give effect to the influence on turnaround time of such factors as average haul and loading-unloading time, the Effective Average Miles per Day per Car with Load (column 12) has been developed. The formula for its calculation can be expressed algebraically as follows:

$$A = \frac{a}{\left(b - 2c^{*} - \frac{bd}{100}\right) \times \frac{e}{100}}$$

Where: A = Effective Average Miles per Day per Car with Load (col. 12)
a = Average Haul per Loaded Car (col. 7)
b = Average Turnaround per Car (col. 6)
c = Normal Free Time for Loading and for Unloading (col. 11, converted to days)
d = Percent of Cars Under Repair (col. 10)
e = Percent Loaded of Total Car-Miles (col. 9)

* For Japan, instead of 2c: The sum of the two figures in col. 11, converted to days.

For the purposes of the equation, it has been assumed that the Percent of Cars Under Repair (column 10) equals the percentage of the time that each car and all cars are not available for loading because of repairs. In multiplying the Normal Free Time (column 11) by 2, it is assumed with some unavoidable inaccuracy, that loaded cars terminated (unreported in the international statistics) are equal in number to those reported as originated. It is further assumed that during the year every car's time is distributed among five possible situations: being loaded; moving loaded; being unloaded; moving empty; or under repair.

There would be some advantage in accumulating the statistics of Statement 6 for the whole of the interconnected standard-gage systems throughout Europe to produce a total more nearly comparable with that of the United States Class I railroads. This is not possible because of gaps in the statistics of some systems, but the inability to produce such a total does not detract from the value of the statistics for the individual systems, the major ones of which (British, French and German), at least, are self-contained to a greater degree than most individual American railroads. In any event, such a continent-wide compilation would be of questionable value for comparison because the statistics of the efficient systems would be comingled with those of the inefficient.

The principal deduction that can be drawn from Statement 6, and particularly column 12, is that American railroads rank third among those compared in effective miles per day per loaded car, but that considering the advantage of the average American haul, far longer than any of the others, the car productivity should be much greater. The first, second and third rankings of Japan, Sweden and the United States in effective miles per day are the same as in loaded miles per year, but thereafter the positions change between the two series. France and Germany follow fairly closely behind the United States on an annual basis, but only Germany does so on a daily basis. If average haul, which intuitively would seem to be the most significant factor influencing car productivity, is plotted against effective miles per day a reasonable straight-line relationship results for all the systems except the United States. If the fitted straight line for the other systems is projected to the 600-odd-mile haul of American railroads, it indicates that the effective miles per day for American railroads should be about 5 times higher than it is. Many differences in geographical conditions and business practices may account for part of this relative ineffectiveness in American car utilization, but it is unlikely that they account for all of it. Some of the differences which do or may exist have been given consideration and will be discussed.

In the smaller countries of Europe (Belgium, Denmark, Netherlands and Switzerland among those represented on Statements 5 and 6) every place is so close to an international boundary that it is natural for a substantial proportion of the traffic to be international (see Statement 7-C). While export and import traffic may nearly offset each other (as do Canadian, Mexican and short-line originations and terminations for American Class I railroads), there is in Europe transit or overhead traffic between countries which has no significant counterpart in the United States. As such traffic is included in the car-miles from which the average haul is calculated but is not included in the originations—and receives no initial or final terminal service on the system reporting the transit miles—an overstatement of effective miles per day results. The influence of international traffic on cars owned (column 2; for foreign countries, more accurately, cars available) is significant only in Switzerland, which reported a positive average balance of interchange cars on-line amounting to 14.3 percent of cars available. The small size of the systems and the related importance of international traffic clearly indicate that the car performance of Belgium, Denmark, the Netherlands and Switzerland is less apt for comparison with American railroads than the records of the systems in the larger countries. For most of the larger countries a comparison of Loaded Cars Handled (column 3) and Loaded Cars Originated (column 4) shows that external influences are minor or offsetting.

Seasonal variations in traffic are greater in Europe than in the United States (see Statement 7-D). This is a logical occurrence in countries with narrower ranges of latitude and climate. Accordingly, seasonal factors can be considered a negative influence in Europe and a positive influence in the United States when comparing car utilization on their respective railroad systems.

National systems probably have more effective control over car distribution than that which presently prevails in the United States. To illustrate: In 1964 the French National Railways originated approximately one-half the number of cars originated on Class I railroads in the United States, and 72 percent of its traffic (in 1960) was domestic and virtually confined to the system. Analysis of the Freight Commodity Statistics for the United States for 1963 (the last year for which they were published for individual railroads) shows that the average ton originated by

Class I railroads moved on 1.8 Class I roads, a composite of 49 percent which were local to the originating line and 51 percent which were interchanged with the participation of an average of 2.6 Class I roads.* Control of the car fleet by approximately 100 railroads has disadvantages compared with a single control center for domestic traffic as in France and most other countries. The deficiency is not unsurmountable, but it should be recognized, and it has been in proposals now under study for centralized car reporting.

Disabilities similar to those that arise from a hundred-odd control centers for car distribution in the United States are also present in the physical performance of interchange. Physical problems which are widespread but individually distinctive cannot be as easily solved as by teaching agreement to establish a national control center, but that they have been recognized is evidenced by quite recent arrangements for running interline freight trains around or through major terminals and by one railroad's development of management control procedures for the movement of cars through terminals.

It might be thought that foreign national railroad systems as government-owned monopolies enforce a high rate of car utilization by prevailing over shippers in ways that would not be feasible in the competitive climate of the United States. If prevailing over shippers means making cars scarce, it falls short of an explanation. The extent of car shortages in other countries is not known, but when there is a car shortage in this country, as far as the shipper is concerned, cars are scarce. Furthermore, as shown by the examples on Statement 7-B, national railroad systems do not necessarily have monopolies of freight transportation.

The average annual miles per car of foreign railroads are benefited by their shorter free times for loading and unloading. It was pointed out by the New York representative of one of the European railroads that the much shorter free times in Europe than in the United States have some validity because the typical European freight car is much smaller than the American one. If normal free time on American railroads were 24 hours at each end instead of 48, the average loadings per car per year would theoretically increase from 15.4 to 16.8, or 9.1 percent, and the average loaded miles per year would increase correspondingly. The productivity of the car ownership would increase by the equivalent of about 150,000 cars. It is questionable whether with the widespread use of mechanical equipment the loading and unloading times of the past are completely realistic (which is recognized on unit-train movements). But some form of revenue concession (as is the case with unit trains) would probably be required to convince some shippers that a reduction in free time represented improved service. Also, the lower train density here than in foreign countries would make it more difficult to provide the more frequent service to industries that in some cases would be required by shorter free times.

A railroad may achieve a high rate of car utilization despite a short average haul if a large proportion of its traffic is in bulk commodities (coal and ore) which provide favorable conditions for good car utilization even on short hauls. From the statistics on Statement 7-A it may be deduced that the coal and ore traffic on the Belgian and Dutch railways is of such proportions that it favorably affects their car utilization rates. The same thing cannot be said for the French railways, where the proportion of coal and ore traffic is almost exactly the same as in the United States. Nor can it be a significant factor in Japan. In the case of Sweden (for which the

* Because of the absence of statistics on the traffic of Canadian and Mexican railroads and short lines, the numbers on which the percentages and averages are based should be considered as relative rather than absolute.

statistics on coal are not available), ore traffic (49.0 percent of tons carried in 1965) on fairly long hauls (averaging about one-half the average of all other traffic) undoubtedly contributed to the high rate of car utilization.

Consideration of bulk-commodity traffic leads to examination of the empty car ratio, shown on Statement 6 as the complementary Percent Loaded of Total Car-Miles. No statistical information is available on directional imbalances of traffic in foreign countries, but the same advantages of geographical expanse that favor American railroads on seasonal variations should also favor them on directional balances.* Again referring to Sweden, reporting 73 percent of car-miles as loaded, if the large volume of ore traffic generated a normal loaded ratio of approximately 50 percent, the loaded ratio of cars carrying the balance of the traffic was obviously even greater than 73. The available evidence is inconclusive as to whether a low empty car ratio is a cause or an effect of a high rate of car utilization, but it tends to imply the latter.

From the facts cited in the preceding paragraphs it may be assumed that some foreign railroads have some advantages over American railroads in the movement and distribution of their car fleets. Some of the advantages are probably inherent in the traffic patterns which are the products of the economies of the countries, while others are the result of the form of organization. Advantages in the latter category point to a large potential for improvement in American car utilization.

CONCLUSIONS

1. For several decades as American freight cars increased in capacity the average load maintained corresponding increases.

2. During the past decade there has been an increase in the proportion of average capacity utilized by the average load.

3. The increase in load-to-capacity ratio has approximately coincided with advancements and refinements in rate technology—specifically, the introduction of incentive rates—and may reasonably be attributed to the improvements in the rate structure.

4. American railroads obtain a better utilization of car capacity in terms of average load than the railroads of most foreign countries which are suitable for comparison. The better utilization is probably the result of differences in the rate structure.

5. Current studies directed to applying computer technology to the compilation and use of American freight tariffs, while retaining the ability to refine rates to meet a variety of specific situations, on the basis of the preceding conclusions are well advised.

6. The utilization of freight cars on American railroads in terms of movement during half a century has not improved to the same degree as several other factors for measuring efficiency.

7. When the productive mileage of American cars is compared with that of railroads in several advanced foreign countries, the United States ranks third, despite average hauls far longer than in any of the other countries.

8. Appraisal of the comparisons referred to in the preceding paragraph indi-

* In the United States in 1962, the last year reported, 54.0 percent of loaded car-miles were east or north by direction and 46.0 percent were west or south. The variation had been decreasing for more than a decade.

Statement 7

Supplemental Statistics
Supporting References in the Text

A. Coal and Ore as Percentage of Total Traffic

United States (1)	Tons Originated	1964	35.0%
Belgian National Rys. Corp.	Tons Carried	1954	59.4
British Rys.	Tons Carried	1964	61.7
French National Rys. Corp.	Tons Carried	1964	35.7
Netherlands Rys.	Tons Carried	1960	50.3
Japanese National Rys.	Tons Carried	1964	19.1

B. Rail Freight Traffic as Percentage of Total by All Modes of Transportation

United States	Ton-Miles	1964	37.5%
France	Ton-Miles	1964	*52.3
Germany (West)	Ton-Miles	1964	*44.9
Japan	Ton-Miles	1964	32.5

C. International Traffic as Percentage of Total Traffic

			Total International Traffic	Transit Traffic
Belgian National Rys. Corp.	Ton-Miles	1954	65.5%	19.2%
Danish State Rys.	Ton-Miles	1964	45.1	14.6
French National Rys. Corp.	Ton-Miles	1960	28.1	2.8
Netherlands Rys.	Ton-Miles	1960	33.6	N.A.
Swiss Federal Rys.	Tons Carried	1963	73.7	22.4

D. Traffic in Highest Month and Lowest Month as Percentages of Year (Average Month = 8.3%)

			Highest Month	Lowest Month
United States (1)	Freight Revenue	**1961	9.3%	7.2%
Belgian National Rys. Corp.	Ton-Miles	1954	10.0	7.3
French National Rys. Corp.	Ton-Miles	1965	9.0	6.6
Italian State Rys.	Ton-Miles	1964	11.0	7.0
Swiss Federal Rys.	Tons Carried	1963	9.9	6.4

Year 1964 is shown when available.

(1) Class I Line-Haul Railroads.
N.A. Not available.
* The total by all modes does not include coastwise shipping, which is probably not significant.
** 1961 was the last year of publication of I.C.C. Statement No. M-100 (monthly); for 1964, the superseding statement, No. Q-100, shows a quarterly pattern not greatly different from that of 1961, but with less variation between quarters.

Sources: (United States) - Various publications of the Interstate Commerce Commission.
(Other Countries) - Principally annual reports, annual statistice and yearbooks of individual railroad systems for specific years.

cates from the record of other countries that there is a large potential for the improvement of the useful mileage productivity of American cars.

9. Taking advantage of the potential for improvement is a goal in current studies directed at a greater centralization of car records and control with the benefit of computer technology and of recent management and operating changes made by some railroads to reduce the time of freight trains and cars in terminals.

10. Expenditures for improved car utilization bring returns in several forms: An improvement of service on existing traffic, making the railroads more competitive; a reduction in the frequency of occasions on which traffic may be lost because of car shortages; a reduction in the requirements for capital—which may or may not be available in the required amounts on acceptable terms—for car purchases; and a probable reduction in expenses incurred for the movement of empty cars.

Advance Report of Committee 16—Economics of Railway Location and Operation

Report on Assignment 4

Potential Application of Electronic Computers to Railway Engineering and Maintenance Problems in Research, Design, Inventory, Etc.

Collaborating as Necessary or Desirable with Committees 11 and 30, the Special Committee on Systems Engineering, and Informally with the Railway Systems and Management Association

G. W. GUTHRIE (chairman subcommittee), L. P. DIAMOND, G. B. DUTTON, JR., R. C. GLIBERT, S. B. GILL, L. W. HAYDON, A. S. LANG, M. B. MILLER, F. N. NYE, W. B. O'SULLIVAN, J. G. SKEEN, W. S. TUNISTRA, J. R. WILMOT, P. B. WILSON, T. D. WOFFORD, JR.

Use of Computer to Analyze Train Delay Problems

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INTRODUCTION

The movement of a train through a railroad complex encounters many opportunities for delay. These delays cost money, and the effort to eliminate delay is never-ending. Yet, to eliminate delay, its extent and cause must be known. Determination of this information generally has been a manual plotting of an actual train's progress with a judgment modification of that progress as result of a planned change. The manual process often becomes tedious and time-consuming, especially if a large number of proposals are involved.

Alternate methods of solution are continually being explored, and the use of data processing equipment is probably the most active. The purpose of this study is to explore the possibilities of using this equipment to solve train-delay problems. Simulation by computer now has been made relatively simple by the very recent introduction of several simulation programs. Simulation of train operation on the Powhatan and Captina Secondary Tracks south of Mingo Junction, Ohio, has been accomplished by utilizing IBM's General Purpose Systems Simulator (GPSS III). We feel the effort has been successful; and the technique can be a valuable tool which should be used more and more, but within the limitations set forth in this paper. The following discussion is not intended to make the reader an expert on GPSS III, but rather to explain how some of the GPSS techniques are used to represent railroad operations. Use of GPSS is fully explained in IBM's User's Manual and, from time to time, the text of this report refers to specific portions of the User's Manual.

RESULTS OF STUDY

A. Why Simulate

Simulation may appear to be some mysterious new technique. Yet, forms of simulation have been used on railroads for years. Train graphs and redispatches have been an accepted part of railroad planning, and this is simulation. In its simplest terms, simulation means a representation of reality. Hence, any verbal description, diagrammed or graphical representation of real life is simulation. Simulation is used to study the effects of change upon various operations. It may be desirable, for example, to know what the addition of a passing siding will do for operations. Obviously, it is too expensive to construct a siding just to find out. Therefore, operations are represented in some abstract form to judge the behavior of the system with a passing siding added. Simulation can be mental. Daydreaming, in some respects, is simulation. Simulation can be manual. Computations by paper and pencil with graphical representations are forms of simulation. Simulation can be performed on a computer. By feeding the computer operating rules, policies, procedures and other elements, the computer will move transactions through time, recording the results. In summary:

1. Simulation is a problem-solving technique
2. It is an experimental method
3. Simulation is resorted to when the system under consideration cannot be analyzed using direct methods

B. Computer Simulation Steps

As in any major problem-solving endeavor, a logical sequence of steps must be followed or solution of the problem will be difficult. Suggested steps for computer studies of train delay are as follows:

1. Determine the objectives of the study and define the problem
2. Thoroughly learn the operations to be simulated. This may require a redispatch of actual trains to gain comprehension
3. Isolate problem areas and develop a number of alternative solutions
4. Prepare a block diagram to represent present and proposed operations. This is best done by using format outlined by the User's Manual
5. Using train records, industrial engineering standard data, time study or estimates of competent supervisors, develop elapsed times for all time-consuming events (except delay) that occur in the block diagram
6. Transfer block diagram information to punched cards. These cards will be the input to the simulation program
7. Run a print-out of the punched cards
8. Review the print-out and eliminate obvious errors, correcting cards as required
9. "De-bug" the program by making a number of short simulation runs. This will be discussed later in the report
10. Perform the desired simulation job
11. Analyze the results and develop conclusions
12. Make appropriate recommendations for changes in operations.

C. Adaptation of GPSS To Railroad Operation

(a) *Generation Of Trains*—Each particular train or group of trains has a pattern of arrival at any given point. Passenger trains may operate daily at nearly the same time each day. Freight trains may also run daily but with quite a variation in arrival times. To illustrate, a passenger train may have the following arrival pattern at a particular station:

Time Interval	*Frequency*
9:55 am to 10:00 am	11% of trains
10:00 am to 10:05 am	62% of trains
10:05 am to 10:10 am	15% of trains
10:10 am to 10:15 am	8% of trains
10:15 am to 10:20 am	2% of trains
10:20 am to 10:30 am	1% of trains
10:30 am to 11:00 am	.5% of trains
11:00 am to 12:01 pm	.5% of trains

Note that this does not indicate what schedule is but what the performance was. When the above information is converted to the proper form, the simulation program will automatically generate a daily train reproducing the same arrival pattern as shown above (Generate Blocks, page 73—User's Manual).

Trains can be generated to represent a particular train by number or symbol or by a group of trains. Trains can be made to operate six days per week by discarding every seventh generation. Five-day-per-week trains can likewise be simulated (Test Blocks—Example 5, Page 89).

In the Powhatan–Captina simulation, the following trains were generated:

Specific Trains:

1. MW-½—Mingo–Benwood Turn
2. Martins Ferry Turn
3. Omal Turn

Group Of Trains As Needed (Mine Runs):

1. Trains serving Powhatan No. 1 Mine
2. Trains serving Powhatan No. 5 Mine
3. Train serving Norton No. 3
4. Trains serving a proposed Norton Mine
5. Trains serving a proposed Y&O Mine

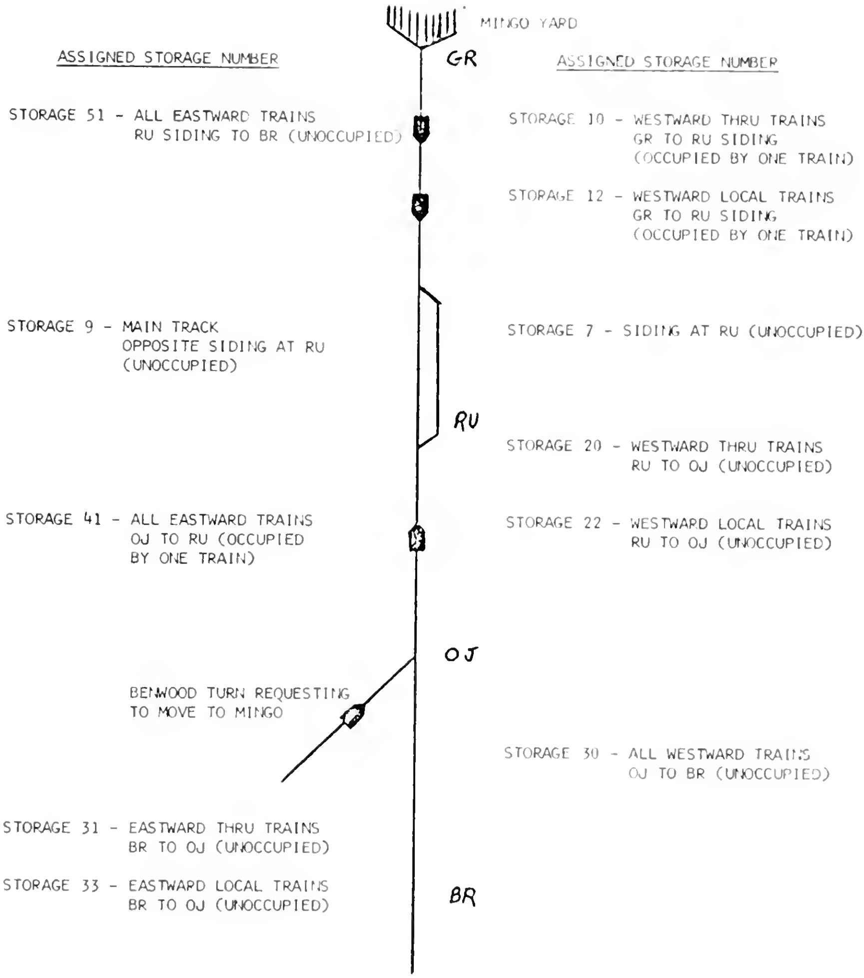
(b) *Train Movement Control*—The present method of operation on the Powhatan Secondary Track is a manual block system with the several blocks defined by block limit stations. The train dispatcher in charge continually studies the progress of the trains running on line, makes decisions and issues instructions to prevent collisions and expeditiously moves the trains. All of this is done within the framework of operating rules prescribed for secondary tracks and manual block.

In the Powhatan simulation, these same rules and decisions were duplicated. Track occupancy between block limit stations was represented by moving trains through portions of track called storages (Storage Block, pages 9 and 154). These storages are chosen and designated so that location of train, direction of train and class of train are always known. Consider an example taken from the Powhatan simulation (Diagram 1). As indicated, Storage 10 can be occupied by only a westward through train and the location of this storage is always between GR and RU. When this train moves past RU, it must enter Storage 20. Since the computer always knows the current contents of all storages at all times, a logic can be devised to control movement of trains just as the dispatcher does (Test Blocks, page 87; or Gate Blocks, page 89; and Variable Statements, pages 10 and 21).

To elaborate on this a bit, Diagram 1 also shows a westward local train in Storage 12 (between GR and RU) and an eastward train in Storage 41 (between

Diagram 1

DIAGRAM SHOWING USE OF STORAGE OCCUPANCY TO CONTROL TRAIN MOVEMENTS



OJ and RU). It is obvious that the two westward trains should meet the eastward train at the siding at RU. A fourth train at this siding would create a "difficult" situation.

When a simulated train arrives at certain check points, it is made to "test" the current contents of a number of storages. If any of these storages are occupied, the train is held until conditions are proper for its release. Where a group of storages are "tested" simultaneously and all must be empty before a train can be permitted to advance, a very convenient method is to test whether the sum of the contents of all the storages equals zero. If any of the storages are occupied, the sum obviously would not be zero; and the train would, therefore, be held (Test Block, Example 3, page 58).

Consider now the Benwood Turn (shown on Diagram 1) trying to gain use of track at OJ:

1. The train would not be permitted in the face of a through train moving BR to OJ (Storage 31).
2. Obviously, if either Storages 20 and/or 22 were occupied, the Benwood Turn must be held or a head-on collision would result.
3. If train in siding at RU (Storage 7) were ready to move, chances are that the Benwood Turn would be held.

Diagram 2 depicts how "testing" the sum of the contents of the storages mentioned above determines whether the Benwood Turn is released, but there are complications. If the Benwood Turn were released on this one test alone, four trains (two each way) would soon congregate at the siding at RU. This is the condition mentioned previously. Additional tests, as depicted in Diagram 2, are made to prevent this situation.

The methods explained above were utilized throughout the Powhatan–Captina problem to control movement of trains and duplicate the operating rules and decision processes of the train dispatcher.

(c) *Proper Storage Entry*—As indicated previously, Storage 10 is always occupied by through trains moving from GR to RU. Consequently, these trains must "know" they are through trains as they move through the program. This is done by assigning a given value to a parameter, which is carried by the trains throughout their lives (Parameters, page 16; Assign Block, page 83).

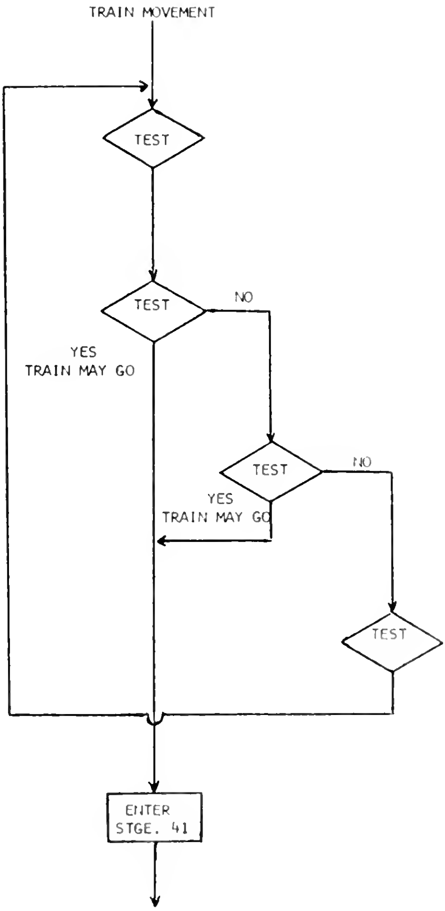
Upon creation, through trains (which is a term we used to refer to all the Powhatan and Captina mine runs) would have a value of 10 assigned to Parameter 1. When these trains left Mingo Yard, they were told by the simulation program to enter the storage specified in Parameter 1 (Indirect Addressing, page 15). In the case of through trains, this would be Storage 10. When trains passed RU, the original value of Parameter 1 was changed by adding 10 to its value (Index Block, page 86). This caused Parameter 1 to have a new value of 20; and, when at RU the trains were again told to enter the storage specified in Parameter 1, they would enter Storage 20.

(d) *Time Spent Running*—The non-stop running time between two points may be nearly a constant (passenger trains) or variable (freight trains depending on power-tonnage ratio). Any type of non-stop running time can be reproduced by assigning running times to a parameter and then referring to it later as the train moves through the advance block within the storage (Advance Block, pages 7 and 67).

(e) *Additional Running Time Account Permissive Blocks and Non-Scheduled Stops At Block Limit Stations and Other Points*—The Powhatan–Captina simulation represented a manual block operation. Under this type of operation, trains may be required to stop at block limit stations to secure block information for the block ahead. Where the block indication is permissive, operating rules require that the train move through the next block at restricted speed. This will consume more time than a straight non-stop run; therefore, additional time must be added. This

Diagram 2

EXAMPLE OF FLOW CHART USING STORAGE OCCUPANCY FOR HOLDING OR CONTROLLING TRAIN MOVEMENT
(REFER TO STORAGE ASSIGNMENTS)



BENWOOD TURN IS AT OJ AND IS READY TO PROCEED TO MINGO.

TEST WHETHER - S20 + S22 + S7 + S31 = 0
MEANING: ARE THERE OPPOSING TRAINS BETWEEN RU AND OJ OR IN RU SIDING READY TO GO OR A THRU TRAIN BY BR; IF SO, HOLD TRAIN UNTIL THE CONTENTS OF ALL ABOVE STORAGES ARE ZERO.

TEST WHETHER S10 + S12 + S7 LE 1
MEANING: IS THERE ONE OR LESS OPPOSING TRAINS BETWEEN GR AND RU; IF YES, TRAIN MAY GO. IF MORE THAN ONE, GO TO NEXT TEST BLOCK.

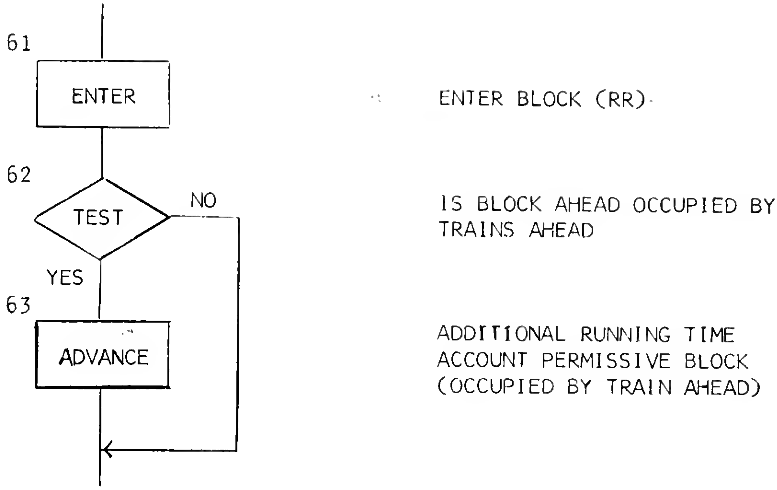
TEST WHETHER S9 + S41 = 0
MEANING: IS THE TRACK AHEAD BETWEEN OJ AND RU EMPTY; IF SO, BLOCKADE AT RU CANNOT OCCUR AND TRAIN MAY GO. IF TRAIN IS AHEAD, GO TO NEXT TEST BLOCK.

TEST WHETHER S9 + S41 = 0
IF NOT, HOLD TRAIN UNTIL IT IS EQUAL TO ZERO. SINCE DELAY AS OCCURRED, ENTIRE SEQUENCE MUST BE RECHECKED; GO TO FIRST TEST BLOCK.

TRAIN ENTER MAIN TRACK
(STORAGE 41)

NOTE:- S20 MEANS CURRENT CONTENT OF STORAGE 20; LE MEANS LESS THAN OR EQUAL TO.

Diagram 3



can be achieved in the simulation by testing whether there is a train ahead in the block just entered. Diagram 3 depicts how the train will bypass the advance block if the block (RR) is clear and how it will pass through the advance block if the block (RR) were occupied by a train ahead.

Where the train is directed through a series of tests at check points (similar to Diagram 2), the train may be delayed. If it is, the train would have had to stop. The time lost by non-scheduled operating stops due to deceleration and acceleration can be substantial and, therefore, must be added to the running time. This can be done by checking whether the train passes through the check points in zero time. If delay had occurred, the time would not be zero, and the additional time for deceleration and acceleration should be added. This is depicted in Diagram 4.

(f) *Working Time At Industries*—To reflect time spent working at industries (including acceleration and deceleration), the time to be worked is assigned to a parameter. Working times are generally variable, and this pattern should be reproduced. Through trains having no work at the industry would be assigned zero working time. When entering the advance block that represents the working time, the train is told to "work" the length of time carried in the parameter.

(g) *Delay Time*—Trains moving through a railroad complex encounter many chances for delay and, if conditions are right, the delay will occur. What happens in simulation is that the known conditions are allowed to act upon the objects (trains) being studied and, where conflicts occur, a train is delayed. The user should insert a queue block in the block diagram (referred to in A—4 of DISCUSSION) where chance of delay exists (Queue Block, page 167). Diagram 5 depicts this condition. The program automatically records the time spent between the queue and depart blocks. Result is later printed at the end of the simulation run.

Diagram 4

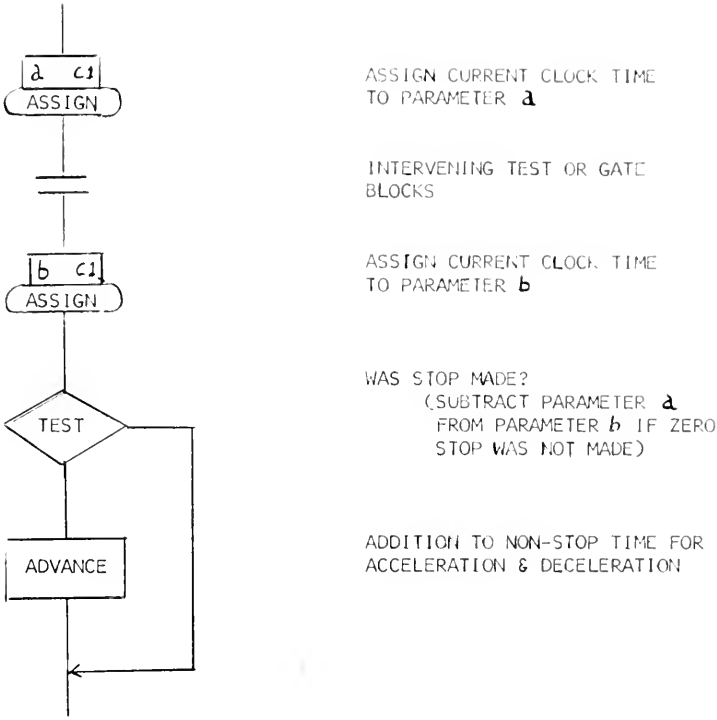


Diagram 5

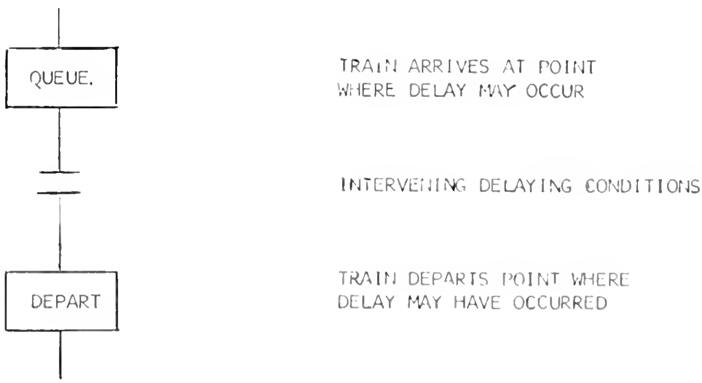
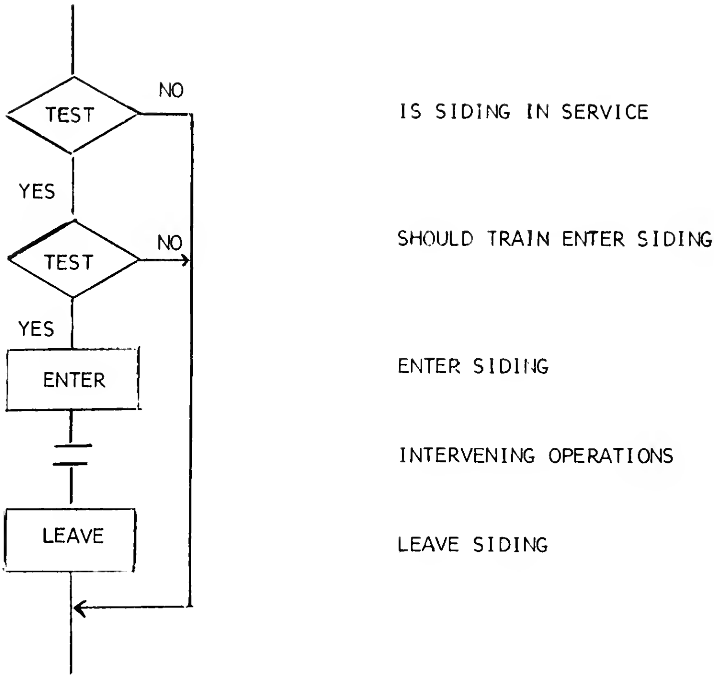


Diagram 6



(h) *Placing New Facilities Into Service*—If a new siding is one of the alternative solutions being considered, the user can place all the operations required at that siding into the original block diagram. These operations should be bypassed (by using a test block) until it is desired to place siding into service. This can then be accomplished by either removing the test block entirely (by just removing card from deck) or by changing the test made (by reading in new variable card). Diagram 6 depicts the situation. This procedure will permit construction of only one block diagram, also saving much de-bugging time, keypunching, card handling, computer time and potential errors.

(i) *Storages Within Storages*—Diagram 1 shows that there are a number of assigned storages between GR and RU. For statistical purposes, it is often desirable to use an additional storage to collect the combined data of all these storages. In the Powhatan simulation, Storages 10, 12, 9 and 51 were combined into a Storage 1. The storage reflects all the time spent within or waiting for clearance to the block between GR and RU. Average time spent in Storage 1 is the average running time between GR and RU.

(j) *Other Statistical Information*—Use of a facility block to gain additional statistical information is quite similar to the use of storages and queues. Facilities were used in the Powhatan–Captina simulation to depict the time spent at coal mines and industries (Facility Block, pages 9 and 139).

Every simulation run provides a block-count print-out which indicates how many trains went through each block of the block diagram. Referring to Diagram 3, the number of trains passing through Block 63 would indicate how many permissive blocks were given during a simulation run. The entries through Block 62 would indicate the total trains passing through the block (RR). From this information, the percentage of permissive blocks can be easily obtained.

The block-count table is very useful to test validity of the simulation program. For example, if 40 trains were generated to work at Powhatan No. 5 Mine and that number did not work at mine (go through facility representing mine), the user knows his program has a "problem" (Block Count, page 47).

(k) *Transit Time*—The time between any two points can be placed into memory. At the end of the simulation run, a table of transit times can be obtained. Entire on-duty times of the crews were simulated in the Powhatan–Captina problem.

D. Use of Statistical Print-Outs

(a) *On-Duty Time Of Train Crews*—Where two methods of operation are being compared, the crew-on-duty table provides a convenient way to evaluate operating costs. Consider two assumed 10-day simulation results:

METHOD A

*Hours On Duty (Upper Limit)**	*Number Observed*	*Percent Of Total*	*Assumed Cost Per Crew***	*Cost Per Hourly Group*
14	3	15	$1,000	$3,000
15	8	40	$1,200	9,600
16	7	35	$1,400	9,800
17	2	10	$1,800	3,600
Total	20	100		$26,000

* On duty between 13 and 14 hours (use 13½ hours for costing)

** Includes crew wages, fringe, car and locomotive ownership, locomotive operation and maintenance, taxi and relief crew if required.

Note—Two trains exceeded 16 hours and required relief.

METHOD B

Hours On Duty (Upper Limit)	*Number Observed*	*Percent Of Total*	*Assumed Cost Per Crew*	*Cost Per Hourly Group*
14	8	40	$1,000	$8,000
15	7	35	$1,200	8,400
16	5	25	$1,400	7,000
17	0	0	$1,800	0
Total	20	100		$23,400

Note—No crews over 16 hours.

Comparison of the two methods indicates that Method B costs $2,600 less than Method A for the 10-day period. This projects to $94,900 annually ($2,600 × 36.5).

(b) *Use of Storage (and Facility) Statistics*—The storage statistics are extremely useful to develop average train hours spent between specific points and to compare changes in train hours produced by different schemes of operations. This can be seen by again using data taken from one of the Powhatan–Captina simulations. Method A depicts present operation and Method B contains operational changes in both Storage 1 and Storage 3.

Storage Number	Average Contents (Trains)*	Entries (Trains)	Average Time Per Train (Hours)	Territory (See Diagram 1)
		Method A—100-Day Period		
1	0.41	917	1.07	GR to RU
2	0.17	917	0.44	RU to OJ
3	0.25	742	0.82	OJ to BR
		Method B—100-Day Period		
1	0.35	921	0.93	GR to RU
2	0.16	921	0.41	RU to OJ
3	0.17	747	0.56	OJ to BR

* Also percent of day occupied by trains.

These tables can be used in two ways to develop the daily savings in train hours. Using Storage 3 for illustration, the two methods are as follows:

Computation Method 1

Train Hours Per Day—Method A (Storage 3)
0.25 (Average Contents) × 24 Hours = 6.00 Hours
Train Hours Per Day—Method B (Storage 3)
0.17 (Average Contents) × 24 Hours = 4.08 Hours
Daily Train Hour Savings—Method B Over Method A
6.00 — 4.08 = 1.92 Hours

Computation Method 2

Time Saved Per Train—Method B Over Method A
0.82 Hours — 0.56 Hours + 0.26 Hours

Trains Per Day (Entries divided by 100)
Method A, 7.42
Method B, 7.47

Average 7.44

Train Hours Saved Per Day, 7.44 × 0.26 = 1.93 Hours

(c) *Use of Queue Statistics*—To illustrate the use of queue statistics, assume that Queue 2 represents the amount of time spent waiting for main track usage at a junction point. Method A represents the present situation and method B represents a change designed to reduce the delay.

Method	Queue Number	Average Contents	Total Entries	Zero Entries	Percent Zeros	Average Time Per Train	Average Time Per Delayed Train
A	2	0.03	557	465	83.5	0.15 Hrs	0.88 Hrs
B	2	0.07	555	415	74.8	0.32 Hrs	1.26 Hrs

The daily number of train hours saved by Method B would be the difference of the contents times 24 hours.

Average Contents, Method A	0.03
Average Contents, Method B	0.07
Difference	—0.04
Hours/Day	—0.96

The conclusion in this case is that Method B does not reduce delay at the junction point but actually increases it. The number of zero entries indicates the number of trains that are not delayed at the junction. The percent of trains not delayed is represented by the column headed *Percent Zeros.* For Method A, the average time spent in delay for all trains, including those not delayed, is 0.15 hours. When a train is actually delayed, however, it will be delayed an average of 0.88 hours.

DISCUSSION

A. Validity of Simulations

The question always arises whether a simulation run is valid. Quite frankly, the answer must be that one never really knows; but, if the project has been done properly, the user can supply such overwhelming supporting evidence that the results can be accepted with a great degree of assurance.

The GPSS program provides the user with many checks and cross-references to provide evidences of validity. If an error occurs during the de-bugging process, the simulation is stopped and an error report is printed, showing exactly at what block the error exists and the type of error involved. In addition, the location of all transactions (trains) at the time of error-stop is given.

However, the most critical part of the entire de-bugging process comes when the program finally runs with no indicated errors. It is at this time the user *MUST* compare what his program is doing compared to what it is supposed to do. It is in this phase that the block count table becomes very helpful. In a train delay study, the user must:

1. Check number of trains generated and terminated.
   (a) Was each class of train generated in the volume intended?
   (b) Was each class of train terminated in the volume intended?
   (c) If generations exceed terminations, will trains enroute at end of simulation resolve the difference?

2. Check flow of each class of train.
   (a) Did the proper number work at intended industry or mine?
   (b) Did the proper number leave or enter main track at the planned locations?
   (c) Did the proper number of trains operate over each portion of main track?
   (d) Was each storage, queue or facility entered by proper number of trains?
   (e) Were passing sidings entered as intended by a "reasonable" number of trains?
   (f) Were decision processes made as intended? This usually can be determined whether alternate paths from test or gate blocks are being used.
   (g) Were the simulated meets, permissive blocks, delay time, operating stops, etc., "reasonable" compared to present operations?
   (h) Were the proper number of trains entered into the statistical tables?

3. Check working times.
   (a) Were times worked at industries and mines as intended?

4. Check simulated times.
   (a) Were average times per train through storages "reasonable" when compared to present operations?
   (b) Can total simulated times for the present operation be closely reconciled to actual times?

5. Check simulated delays.
   (a) Was simulation accomplished with no unusual or unexpected heavy delays at all points?
   (b) Was maximum number of trains waiting at any one location "reasonable" compared to actual operations?

If the answer to each of the questions asked above is affirmative, there is strong evidence that the simulation is valid.

B. When To Use Computer Simulation

Simulation by computer works and is a valuable tool, but this should not exclude other methods of solving delay programs. Before a decision is made to solve a problem by any particular method, several situations must be carefully weighed.

1. *Length Of Time Available to Make Study*—The preparation of a statistical analysis of a problem, such as described, by computer requires approximately two man-months of effort. Unless a data bank of required data is readily available, computer simulation is not a practical way of solving problems requiring an immediate answer. Generally, a "crash" project is a result of some poor prior planning. It is suggested here that use of computer simulation on the long-range planning problems would reduce incidence of emergency decision.
2. *Accuracy Of Study*—The cost of making a computer simulation is high, but, once the program has been prepared, many alternate decisions can be run at very little additional cost. This enables a more thorough exploration of all possible avenues of approach, and this should result in a better study. Often, when a manual redispatch is used, only one proposal is tested for a short period of time (a week or two). Where train volumes are variable, this may not give a valid sample. The general tendency is to pick a heavy traffic period, using the philosophy that, if the proposal works during a heavy period, it will work during a slack period. Savings derived from this selected heavy period definitely will not be representative. Savings will be overstated by an unknown and undeterminable amount. Computers in a few minutes can simulate a length of time long enough to dampen out the effects of peak periods. Savings from this source should be representative. Thus, if the only question to be answered by the study is: Will it work?, a manual redispatch of a heavy period would appear to be the best method. However, where comparisons of operating costs are to be made, simulation should be made over a period of time sufficiently long to eliminate any "sampling error." This may or may not be performed by the computer.
3. *Cost Of Making Study*—It should go without saying that cost of making the study should govern what technique is used. The problem to be reconciled here is that the study-cost comparisons should represent equal-quality studies. A comparison of study costs of slipshod analysis to a thorough, detailed analysis is not legitimate.

C. Disadvantage of GPSS

Experience from the Powhatan simulation indicates that the portion of railroad that can be covered by one model is limited. The Powhatan model represented a relatively small portion of railroad (55 miles), but certain features of the program were at the maximum limits. In light-traffic areas, the length of the track modeled can be extended by reallocating core storage reserved for one portion of the program (but not used) to another portion. This will permit a larger model. In heavy-traffic territory, the core storage available may become a distinct problem. Just how great a problem this will be remains to be seen by additional experience.

D. Study Team

For best results, members of operating management must take part and be an integral part of any computer simulation team. Reasons are two-fold:

1. Any study of this nature made without participation is automatically suspect, especially if the answer is contrary to preconceived opinions.
2. The mystery and distrust of the computer itself will slowly evaporate when the operating personnel see their problems solved with the very information they helped develop.

Advance Report of Committee 16—Economics of Railway Location and Operation

Report on Assignment 6

Features of Economic and Engineering Interest in the Study, Design, Construction and Operation of New Railway Line Projects, or Major Line Relocations, Proposed, in Progress, or Recently Completed

H. L. Woldridge *(chairman, subcommittee)*, R. S. Allen, J. L. Charles, R. C. Gilbert, S. B., Gill, R. A. Hartselle, G. Hartsoe, G. A. Jacobs, R. J. Lane, H. A. Lind, R. McCann, D. McCorquodale, T. C. Nordquist, J. G. Skeen, W. S. Tuinstra, P. E. Van Cleve.

Under this assignment your commit.ee presents two papers. The first, by T. C. Nordquist, describes the construction and operation of a spur track built on a 5.6 percent grade to serve the Boeing Company near Everett, Wash. The second, by J. L. Charles (see page 83), discusses a proposed Zambia–East Africa rail link.

Construction and Operation of a Spur Track Built on a 5.6-Percent Grade to Serve the Boeing Company Near Everett, Wash.

By T. C. NORDQUIST
Principal Construction Engineer, Great Northern Railway

On November 10, 1966, dedication ceremonies were held to open the spur track serving the Boeing Company's 747 Jet Transport Plant site near Everett, Wash.

The construction of this spur was an answer to the challenge to provide rail service to an industrial complex remote from rail service and whose product was not fully oriented to rail handling. It also illustrates what the future holds for railroads in the way of providing rail service to industry. With the increased growth of this country, areas available to industry become increasingly adverse to rail service and yet meet the demands of the area served. Therefore, it is now necessary for the railroad industry to take another look at its design criteria for grade and curvature in track construction, and develop new standards that incorporate the use of modern-day power available plus materials and techniques that can be employed in building a track grade and structure.

The track built is approximately 1.7 miles long and on a 5.6 percent grade with a maximum curvature of 13° and 12 more curves varying from 10° 10′ to 2° 00′ for a total central angle of some 417° 27′ 11″. The track is located in a narrow, steep-sided and heavily wooded ravine called Japanese Gulch. The location of the spur was dictated by the necessity of building a plant of this type adjacent to a large airport; and despite the fact that the gulch was originally scoured by the melting of a glacier out of a glacial till, which becomes highly unstable in the presence of water, it was determined that this was the only feasible location to build a spur to the plant site from the Great Northern's main track between Seattle and Everett.

It was about 6½ months prior to the dedication that representatives of the Boeing Company requested the Great Northern to explore the possibilities of building a spur track to this proposed plant at the north end of Paine Field. Three locations were investigated; and of these three, Japanese Gulch offered the best route despite the presence of the stated poor soil conditions. The Austin Company was employed as a prime contractor for the entire project, with the engineering being done by their affiliate, Austin Associates. The basic design criteria and construction details were specified by the railway company's engineers; but the prime contractor had the full responsibility of all the details and plans for construction subject to the railway company's approval.

The location of the spur also dictated revisions in the operating facilities of the Great Northern's main track; and in order to handle the anticipated traffic to the plant, consideration had to be given to the construction of an additional set-out track at Mukilteo and to extension of CTC to the next station west at Edmonds. Also, thinking was started on how trains must be handled on the spur and what precautions should be made. Summary of this will be made later in the report.

The basic design criteria as set up by the Railway Company were as follows:

Grading:

(1) Maximum curvature of 13° with grade compensation of 0.04 percent per degree of curve.
(2) Embankment at shoulder to be 22 ft wide.
(3) Maximum grade to be less than 6 percent.
(4) Slopes of embankments not to exceed 1½:1.

Track:

(1) Rail—Secondhand 112 lb.
(2) Ties—Creosote treated, Grade No. 5, softwood, 23 per panel.
(3) Rail Anchors—33 per track panel.
(4) Ballast—Crushed rock, 2½ in minus.
(5) Sub-ballast—Select gravel, 12 in. in depth.

Drainage Structures Under Track:

(1) Corrugated metal culvert pipe, minimum diameter 24 in, 12 gage galvanized, asbestos bonded, and asphalt coated.
(2) Concrete pipe, 24 in minimum diameter, ASTM C 76, Class IV, Wall B.

A preliminary survey line was opened through the dense cover early in May and followed with clearing of the right-of-way on June 13. Grading was begun a week later, and at the same time the railway company started its own grading and related work to construct a set-out track and two complimentary crossovers adjacent to its main tracks at Mukilteo. Grading up the gulch was progressed at a rapid rate despite the poor soil conditions. To illustrate the soil conditions encountered, a general soil profile is as follows:

(1) *Sea level at Puget Sound to elevation of 100*—Clay silt with associated water on its upper contact zone. This water in turn contributed to the instability of overlying sandy soils. Material would stand at steep slopes but would be subjected to extensive periodic sloughing.

(2) *From elevation 100 to elevation between 120 and 140*—Sand and gravel, generally wet and will stand on a slope no steeper than 3:1.

(3) *From elevation 130 to elevation 330*—Glacial till, very compact and resistant to erosion and very steep-sided. Seepage existing along upper limit which is clay.
(4) *From elevation 330 to elevation 500*—Fine to medium sands, very compact and able to stand on a slope as steep as 1½:1.
(5) *Elevation 500 to surface*—Overlying blanket of glacial till, being very compact.

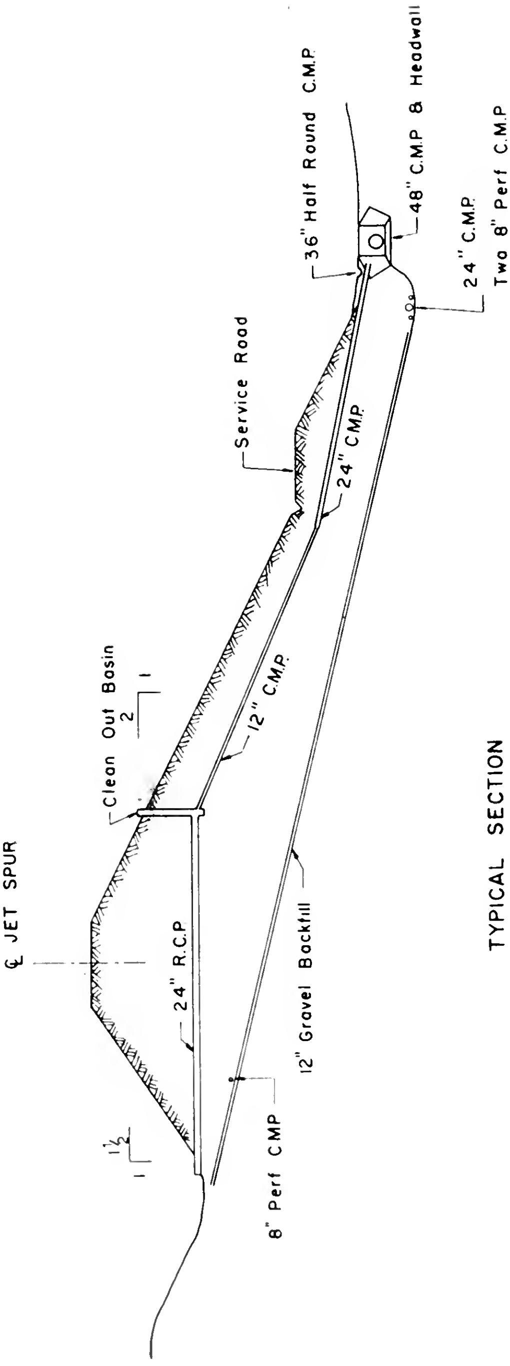
In order to maintain and control drainage, an extensive system consisting of perforated culvert pipe, flumes, culverts, and ditches was developed and constructed. Rainfall in the area averages 35 in annually and with most of it falling in the period of October to February, a well planned and coordinated system was dictated. At the end of the construction, a total of 64,823 ft of drainage structures had been placed. This consisted primarily of 45,078 ft of corrugated metal pipe ranging in size from 8 to 54 in; 9,495 ft of 36-in half-round flume; 2,580 ft of reinforced concrete pipe ranging in size from 24 to 60 in; 6,200 ft of 12-ft-wide rock-lined ditch including 16 concrete weirs; and 1,470 ft of 48-in concrete pipe outfall storm drain. All of this was placed in approximately three months time, including the clearing of over 94 acres and the movement of 1,574,000 cu yd of earth fill. As all native materials were used in the construction of the fills, this necessitated compaction by machine in excess of 95 percent. After slopes had been dressed off, seeding with quick germinating grasses followed to obtain cover on the bare fill and thus prevent raveling of the slopes during the rainy season.

Most of the track is built on fill carried in a side-hill position which also spans over more than one type of soil condition. This in turn exposed the fill to water seepage which would create slippage planes between fill and natural ground. Fig. 1 illustrates a typical section of the fill and what was done to eliminate the water problem. The placement of the 12-in gravel blanket and the 8-in perforated pipe laterally to the track did much to expedite the elimination of the water in that plane between fill and natural ground. The system of cross drainage illustrated was used extensively for water elimination through and across much of the fill for entire track.

As hereinbefore stated, early consideration was given to the operating problems that would be encountered on a spur with such a heavy grade. Two types of locomotives were investigated and it was determined that the SD-9 type was best suited for this work, with, however, the maximum gross trailing tons not to exceed 350. The other approved type was the GP-9 locomotive with a limitation of 200 trailing gross tons.

The operating department had examined certain trainmen and enginemen qualified to operate trains on the grade. The crew must have their caboose on the high end of the train both ascending and descending the grade, and the operating speed in both directions was not to exceed 10 mph.

Rules also provide that an engineer before ascending the grade must inspect and test the air-brake equipment on his locomotive and must know that the air brakes as well as the dynamic brakes are in operative condition before leaving the terminal. This same series of inspections and tests must be done at the high end before descending the grade. Also, a test must be made of the effectiveness of the train air brakes, brake pipe pressure-maintaining feature, and the dynamic brake before operating on the grade in either direction. The engineer must know that the diesel engine has sufficient fuel, oil, and cooling water and that the lubricating



TYPICAL SECTION
LOOKING SOUTH

Fig. 1

oil is being carried at the low mark. Sanders must be inspected and known to be in operating condition on the locomotive. Every locomotive operating on the grade must carry wheel blocks. If for any reason the diesel engine is stopped, or the dynamic brakes become inoperative, the movement must be stopped and all hand brakes applied; and if the air compressor is not operating, the locomotive must be blocked. When descending the grade, the retaining valves must be turned to high position on all loaded cars.

After reaching the apex of the 5.6 grade, all of the yard tracks continue on a critical 1.7 percent ascending grade. This requires all cars to be left or spotted on these tracks to have an air set with full service reduction, hand brakes applied, and rail clamps set against the wheels on one rail to prevent a runaway.

In addition to the above safety regulations, two spring switch derails were installed at key points on the track, the first one being at the top and in front of the yard and spur tracks serving the various buildings of the Boeing plant. The second one was located about three-quarters of the way down the grade and set so that a runaway car would derail into the bank. Each of these must be hand thrown to align for the main spur operation by the descending train. The main track at Mukilteo is within CTC territory; and, therefore, it is necessary for the switch crew to telephone the dispatcher at Seattle for permission to enter onto the main track.

During peak construction of the plant itself, the traffic movement has reached 20 cars a day. The last figures available indicate that an estimated 10 cars per day will move into the plant with materials for construction of the Boeing 747 airplane. The movement of the traffic is all inbound and therefore trains must ascend the grade under load. The product of the plant, of course, is airplanes; hence, there is no outbound traffic. It is possible that other satellite industries will develop adjacent to the main plant, all of which will add to the inbound movement.

Proposed Zambia–East Africa Rail Link—British–Canadian Survey 1966

By J. L. CHARLES,
Consultant on Railway Location

INTRODUCTION

In Africa, by the beginning of the Twentieth Century, railway construction was being pushed from coastal ports towards the hinterlands.

In 1905, Rhodesia Railways opened for traffic its magnificent bridge crossing the scenic gorge of the Zambezi River, below Victoria Falls, and shortly extended railway operation to Ndola, in the "Copper Belt," near the Zambia–Congo Border.

Rhodesia Railways serves "landlocked" Zambia with its route for exports southerly and easterly, through Bulawayo and Salisbury, Rhodesia, and thence through Mozambique (Portuguese) to the port of Beira, at the Indian Ocean, a distance of 1460 miles.

From Bulawayo, another line of Rhodesia Railways runs southerly to connect with lines of the South African Republic to Capetown.

At the "Copper Belt" there is connection with the railway operating through the southern area of the Congo, thence westerly through Angola (Portuguese) to the Atlantic port of Lobito, a distance of 1480 miles.

East African Railways and Harbours, which serves Tanzania, Kenya and Uganda, was constructed from Indian Ocean ports—Dar-es-Salaam, Tanga and Mombasa to Lake Tanganyika, tributary to the Congo, and to Lake Victoria at the headwaters of the Nile.

There is a long "gap" between Rhodesia Railways and East African Railways and a difference in gages—3 ft 6 in and meter (3 ft 3⅜ in), respectively. If these two systems could be linked, landlocked Zambia would have an alternative rail route to the Indian Ocean, at Dar-es-Salaam, Tanzania, entirely through country controlled by Africans and it would be somewhat shorter than the existing route to Beira, Mozambique. (See Plate I).

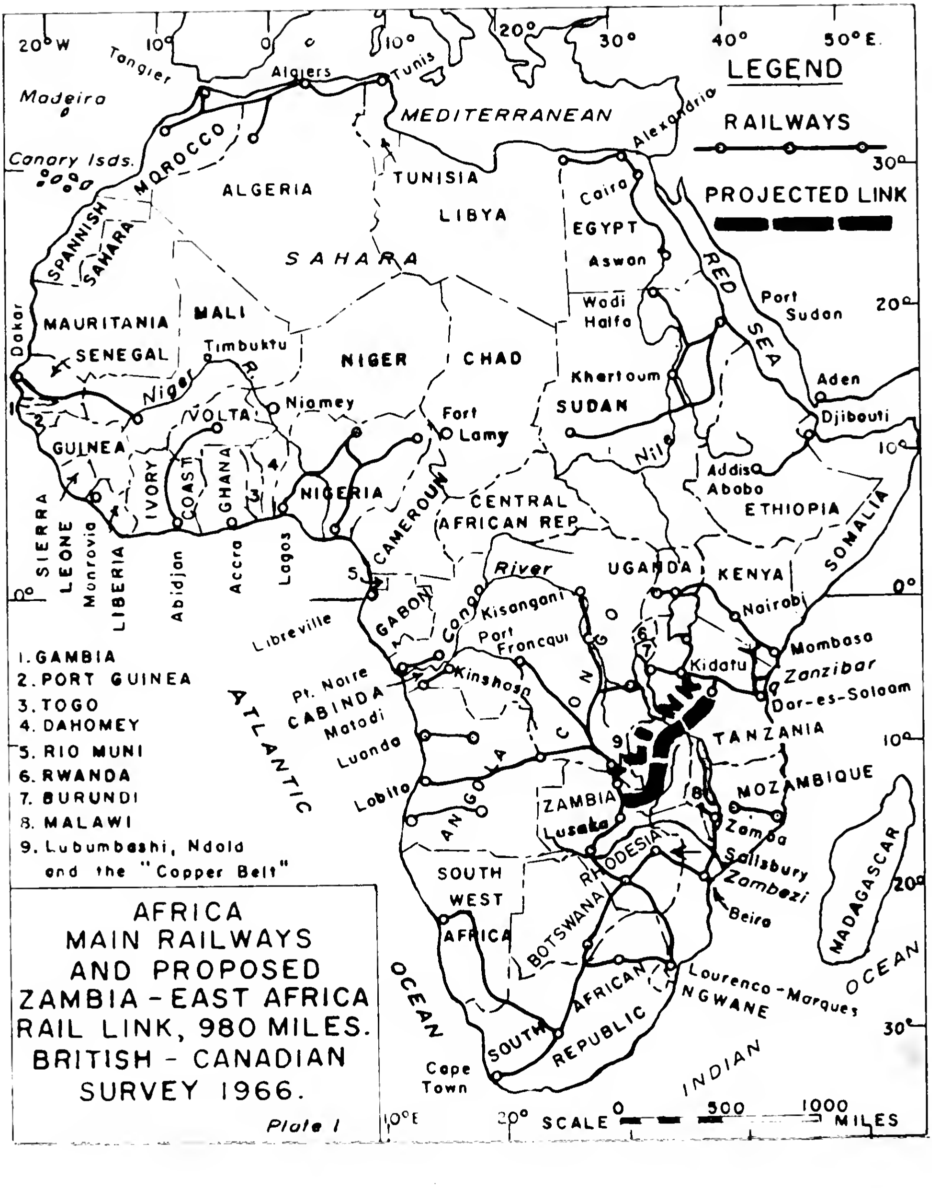
Reconnaissance and preliminary surveys were undertaken from 1949 to 1952 to determine the feasibility of construction of a railway to link Rhodesia Railways and East African Railways. A location was projected, 1150 miles in length, and a very comprehensive report was compiled, under administration of East African Railways and Harbours.

From 1963 to 1965 East African Railways undertook more detailed surveys from its Central line southerly to the Kilombero Valley and beyond to Makumbako, resulting in construction of a branch line, 67 miles in length, from the Central line, at Kilosa, to Kidatu, and reduced the "gap."

When the Federation of Rhodesia and Nyasaland dissolved, Northern Rhodesia became the Republic of Zambia (1964), and Rhodesia (formerly Southern Rhodesia) made the "Unilateral Declaration of Independence," rail transportation to and from Zambia became vulnerable.

In 1965 and 1966 Great Britain and Canada jointly sponsored "A British–Canadian Report on an Engineering and Economic Feasibility Study for a Proposed Zambia–East Africa Rail Link" for the Inter-Governmental Ministerial Committee for the Zambia–East Africa Railway (acting on behalf of the Governments of Tanzania, Uganda, Kenya and Zambia).

The objective of this paper is to describe the survey to establish the railway location and design.



AFRICA
MAIN RAILWAYS
AND PROPOSED
ZAMBIA - EAST AFRICA
RAIL LINK, 980 MILES.
BRITISH - CANADIAN
SURVEY 1966.

Plate I

ORGANIZATION AND WORKING CONDITIONS

Personnel engaged in the field on the railway location survey consisted of the chief engineer, project manager, light aircraft pilot, mechanic, camera man and electronics technician, helicopter pilot and mechanic, three engineers and one surveyor with three technical assistants, supplemented part time by a specialist in tropical soils and air photo interpretation, plus four Zambian drivers, a total of 19 men.

There are two definite seasons in this area of Africa—dry and wet. This survey had to be carried out during the wet season, December through March. Sudden, violent electrical storms with heavy downpours were frequent and restricted operation of light aircraft. Cloud cover was heavy, limiting aerial photography.

The proximity of the Great North Road, gravel surface, was very helpful for the southerly 750 miles, but beyond, for 200 miles, there were no trails open for vehicles during the rainy season.

SURVEY METHODS

General reconnaissance was carried out from light aircraft. Then closer observations were made from light helicopter and on the ground. As the route was established, aerial photography was obtained and surveys were run to set ground control stations, as necessary, for photogrammetric mapping; together with air photo interpretation, soils investigation to furnish the data required for projection of the railway center line and the relative profile; also for design of the formation, structures and for estimates.

Reconnaissance

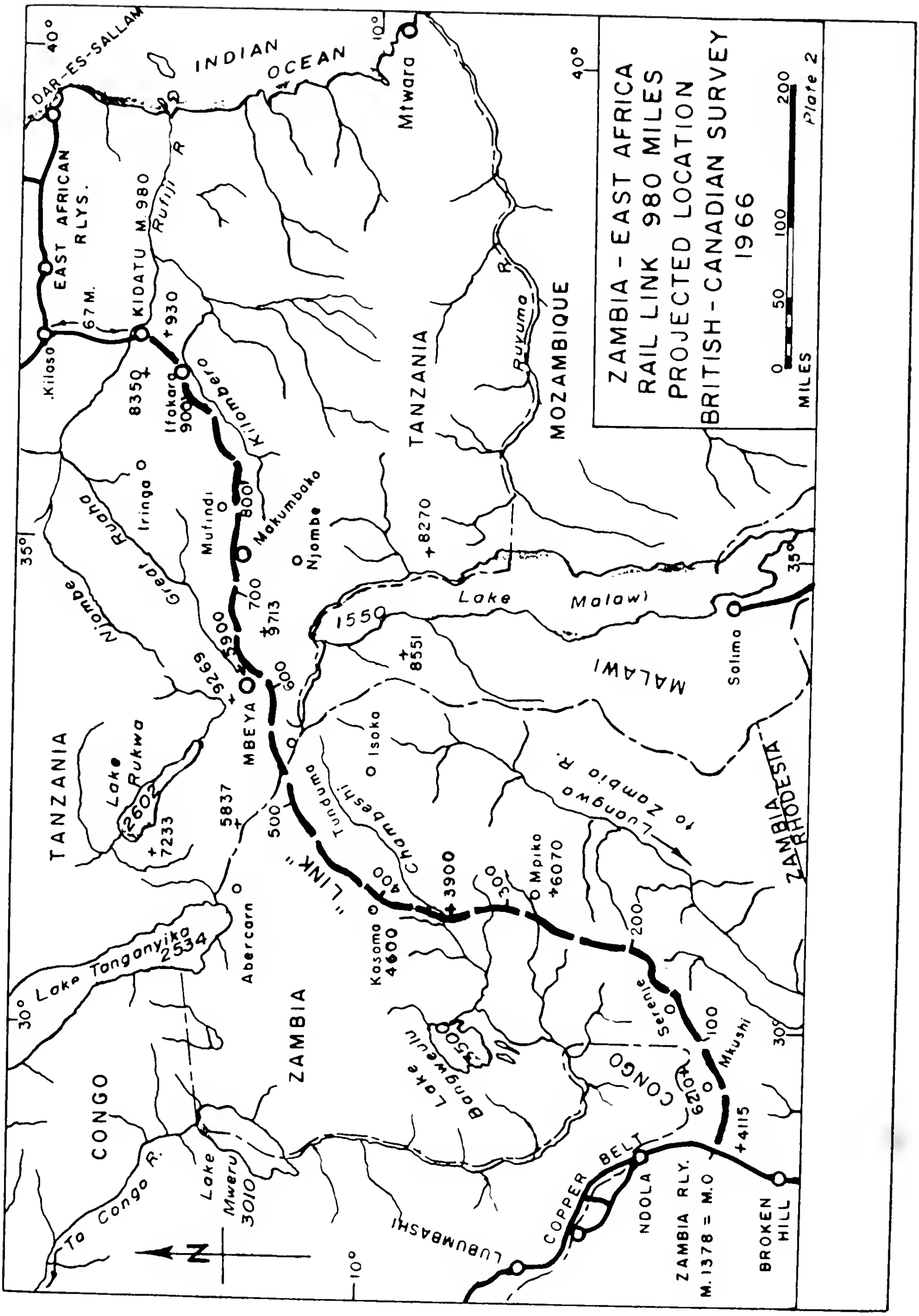
The shortest distance between the Rhodesia Railways in Zambia, and the East African Railways in Tanzania, would be from Ndola northeasterly to Kidatu. However, the boundaries of two neighbor nations—the southern extremity of Congo and the northern tip of Malawi—were geographical features to be considered. (See Plate 2.)

During initial flights, the principal topographical features were observed to be:

(1) The "hog's back"—shown on some maps as the Muchinga Mountains —which runs from the "Copper Belt" for some 500 miles north-easterly to the border between Zambia and Tanzania. From this watershed, westerly drainage is to the Chambeshi River, thence to the Congo River and Atlantic Ocean; easterly run-off is to the Luangwa River, tributary to the Zambezi River and Indian Ocean.

(2) The above two drainage systems also receive the outflows from Lake Tanganyika and Lake Malawi, respectively. These two great lakes are relative to the famed Rift Valley, and the country about them is spectacular, especially along the east shore of Lake Malawi, where the steep slopes of the Livingstone Mountains rise from lake level, 1550 ft, to peaks over elevation 8000 ft; underwater slopes are also steep, for Lake Malawi has depths to 2200 ft.

(3) The Zambia–Tanzania boundary is along a prominent "Range" with elevations up to nearly 6000 ft between the north end of Lake Malawi and the south end of Lake Tanganyika. Northward from this "Border Range" there are steep descents into valleys of the Songwe River, tributary to Lake Malawi and to streams flowing to Lake Rukwa.


ZAMBIA - EAST AFRICA
RAIL LINK 980 MILES
PROJECTED LOCATION
BRITISH-CANADIAN SURVEY
1966
0
50
100
200
MILES
Plate 2
INDIAN
OCEAN
DAR-ES-SALLAM
EAST AFRICAN
RLYS.
Kiloso
67 M.
KIDATU M.980
+930
Rufiji
R
Mtwara
TANZANIA
MOZAMBIQUE
Ruvuma
R
Ifakara
900
Kilombero
8350
Iringa
Mufindi
800
Makumbako
Njombe
+8270
Great
Ruaha
Njombe
700
+713
5900
+9269
MBEYA
600
Lake
Malawi
1550
+8551
MALAWI
Salima
Isoka
Tunduma
Chambeshi
to Zambia R.
Luangwa
TANZANIA
Lake
Rukwa
2602
+7233
+5837
500
"LINK"
400
+3900
300
Mpiko
+6070
200
Kasama
4600
Abercorn
Lake Tanganyika
2534
ZAMBIA
RHODESIA
Serenje
100
Mkushi
CONGO
6210
+4115
Lake
Bangweulu
3500
ZAMBIA
CONGO
Lake
Mweru
3010
To Congo R.
LUBUMBASHI
COPPER
BELT
NDOLA
ZAMBIA RLY.
M.1378 = M.0
BROKEN
HILL
N
10°
30°
35°
40°

(4) Salaga Pass, elevation 5900 ft—between Mt. Mbeya, 9270 ft, and the Poroto Mountains, up to 9700 ft—at the headwaters of the Great Ruaha River flowing north-easterly, thence easterly to the Rufiji River and the Indian Ocean, just south of Dar-es-Salaam.

(5) Makumbako divide, elevation 5400, and descent by Mufindi Escarpment to the Kilombero Valley, elevation 1000.

(6) Kilombero Valley, a vast flood plain, general elevation 900 ft, is inundated at times up to 35 miles wide by overflow from the meandering Kilombero River and its tributaries. However, the north-westerly side of the valley is very distinctly defined by the toe of a mountain range, with peaks up to 8350 ft.

Marketing Centers and Products

Intermediate administrative and other centers to be considered with respect to potential rail service and traffic are:

In Zambia—Mkuski River, Mpika, Kasama and Abercorn; also, Chinsali and Isoka.

In Tanzania—Mbeya, Makumbako, Mufindi and Ifakara; also, Iringa.

Commodities to be transported include: (a) through traffic—export of copper, lead and zinc, and import of petroleum products, mining and agricultural equipment, etc., through Dar-es-Salaam, (b) to and from intermediate stations—agricultural and forest products, such as maize, tobacco, coffee, tea, sugar and timber and perhaps pulp.

Study of the above-mentioned general features, and closer observations by helicopter and on the ground indicated that the proposed "Link" should turn off from Rhodesia Railways near Kampoyo, 70 miles south of Ndola, to run through the Salaga Pass, east of Mbeya, to connect with East African Railways at Kidatu.

After several alternative intermediate routes had been reconnoitered, the route finally adopted was one which would pass 20 miles west of Mpika, thence almost due north across the Chambeshi River to Kasama, then north-easterly to cross the border west of Tunduma and continue in the same general direction to Mbeya. Although, compared with some of the alternative routes, this line involved additional "rise and fall" to cross the Chambeshi River and a major bridge, 600 ft long, it avoided intruding on Malawi, or introducing adverse direction; also, this line passed through Kasama, the important administrative center of northern Zambia, with good highway connection to Abercorn and water transport on Lake Tanganyika.

From Makumbako to the Kilombero Valley there is a descent of 4360 ft in 100 miles, with local summits to be surmounted within this distance. This is by the toe of Mufindi Escarpment, through extremely broken "jumbled-up" country, with numerous landslides caused by severe erosion and/or slumps which may be brought about by subterraneous water in deep silty micaceous soil.

These conditions present a major challenge to railway location, construction and maintenance. All alternatives which might avoid them were examined, but were subsequently eliminated. The entire route was covered several times by ground and air transport, including at least 6600 miles by helicopter.

Other very rugged areas where especially close examination was necessary were:

(1) Kasama Ridge and ascent to the Zambia–Tanzania Border.

(2) From the "Border" to descend 900 ft, along steep side-hill formation, to the Mpemba River and a further 960 ft to the Songwe River, towards Mbeya.

(3) From Salaga Pass, elevation 5900, along steep slopes of the Poroto Mountains, with some volcanic ash soils, eroded by numerous ravines up to 500 ft deep, to reach more gentle slopes skirting the Buhoro Flats, elevation 3500.

There are no practical alternatives to location through these three rugged areas.

As reconnaissance proceeded, the air photo coverage required was outlined, and the strips to be mapped were delineated for guidance of the parties on aerial photography and on ground controls. Soils investigation was also carried out and samples taken for laboratory analysis.

Mapping

Strip maps were compiled at a scale of 1:12,000, showing contours with vertical interval not more than 20 ft, over the entire route. Profiles were projected at the same horizontal scale, with vertical scale 1:1200. Also, a general map and condensed profile, scale 1:1,000,000, was drawn to show on one sheet, the principal controlling features with respect to one another and the overall situation.

SOILS

The engineering significance of soil and geological information is, with respect to:

Zambia

The bedrock of the pertinent area is composed of geologically old Basement Complex and younger formations including gneiss, dolomite, quartzite and slates; there are granite and other intrusions. The bedrock is weathered to varying depths with hard rock close to the surface at high knobs and ridges.

In general, the proposed line traverses in well drained sandy soil, laterized to various degrees.

There are two other major types; they include a section of say 50 miles in the vicinity of the Chambeshi River, south of Kasama, that is composed of lake-bed silty material, and a section of about 20 miles adjacent to flood plains at the toe of the "Border Range."

Thus, the soil condition along the route through northern Zambia, as a whole, is favorable for railway construction because of its well drained nature, stable slopes and high bearing capacity. Poor soil areas and high water-table conditions are at a minimum.

Tanzania

The bedrock of the area through which the "Link" is projected is composed of geologically old Basement Complex of metamorphic rocks, including gneiss, schist, quartzite and crystalline limestone. Younger sedimentary and volcanic deposits as well as intrusions are also present.

In particular, significant volcanic deposits are located in the Mbeya area and easterly on the slopes of Poroto Mountains.

The proposed line traverses in highly varying soils, including well developed lateritic soils, thin to very deep residual soils, volcanic soils, recent alluvial deposits and talus and slide material.

Soil condition in this part of Tanzania is generally less favorable for railway construction compared to that in Northern Zambia.

Indeed, the soils in one major area—between Makumbako, by Mufindi Escarpment, and the Kilombero Valley—present some most difficult earthwork problems.

Three typical samples of soils from this critical area, designated A, B and C, have been examined and particle-size analysis and drained direct shear tests on remolded specimens have been carried out under normal pressures of about 2 tons per sq ft. From these tests, values of the angle of shearing resistance in terms of effective stress have been obtained, together with water contents at failure. The results are given below.

	Particle-Size Analysis				*Shear Test*	
Sample	*Gravel, Percent*	*Sand, Percent*	*Silt, Percent*	*Clay, Percent*	*Angle of Shearing Resistance, Degrees*	*Water Content at Failure, Percent*
A—Reddish Color	0	48	23	29	33.5	27.2
B—Pinkish Color	0	51	40	9	33.0	28.7
C—Brownish Color	0	77	21	2	30.5	45.5

The "A" material is satisfactory for the construction of embankment. It should compact well and is relatively stable.

The "B" material is far less satisfactory; it has a very low dry strength, and will also erode very easily.

The "C" material contains a great deal of mica and will be very unsatisfactory for use as fill material. It will not be possible to compact this material and it will erode very easily.

It may prove possible to use some of the "B" material inside the embankments provided it is protected by an adequate thickness of superior material.

Through the Kilombero Valley, the proposed "link" is projected close to the toe of the mountain slopes of various metamorphic rock formations to the west. Except for short stretches where minor excavations are in rock, the line generally traverses in soils of talus material, alluvial fans, and flood plains of sand, silt and clay. Locally there are salts and high-ground water conditions.

Critical Areas

The extensive, deep, silty, micaceous soil between Makumbako and the Kilombero Valley is the most critical area on the whole line. There are many landslides and extensive erosion in this soil. Rock might be encountered at depth, and in some river beds, also, residual boulders are scattered over the area.

The deep deposits of highly erosive and low-shearing-strength, silty, micaceous soil compounded with the prevailing rugged topography entails special design measures. However, it is believed that useful embankment material is available in that general area and with proper cut and fill slopes, construction is feasible.

Less serious but requiring special consideration are conditions in the areas of highly erosive volcanic ash deposits east of Mbeya.

Shallow cuts in volcanic silts as well as in mature sandy soils could stand at near vertical slopes but deep cuts would need to be stepped.

PROJECTION AND DESIGN

Most of the existing railways in East Africa were constructed with hand labor and limited mechanical equipment; therefore, comparatively heavy curvature and rise and fall were introduced to keep deep excavations and high embankments to a minimum.

Now, with demands of traffic and availability of modern construction equipment, extensive betterment programs are in progress. Therefore, it is assumed that the alignment and gradients for future railways should be designed for construction with the latest classes of equipment as may be practicable with available labor and consistent with overall economy.

Guided by the general principles established by the late A. M. Wellington in his "Economic Theory of Railroad Location" with respect to potential traffic, capital cost and interest in relation to expenditures for maintenance of way and operation, and by the controlling factors observed—geography, industries, topography, soils and climate—affecting this proposed "Link", the following criteria were adopted:

Gradients and Curves—Maximum Rates

Controlling elevations (see Plate 3) and relative distances between them indicated that it would not be economically practicable to adopt lower maximum rates of gradients and curvature than:

Mile and Mile	*Gradients, Percent, Comp.*	*Rate of Curve*
0—385 near Kasama	1.00 both directions	4 deg
385—753 Makumbako	1.50 both directions	6 deg
753—873 Chita	1.50 against northward 2.00 against southward	8 deg
873—980 Kidatu	1.00 both directions	4 deg

Division Yards and Passing Tracks

Selection of sites for these facilities had a direct effect on the design of gradients.

Lengths of operating divisions recommended on this "Link" are from 111 miles to 175 miles, controlled largely by traffic, topography, established centers of population, gradients and curvature affecting train operation.

Intermediate passing tracks, 2500 ft long, are planned at distances of up to 15 miles, where gradients and curvature are comparatively light, and up to 10 miles apart on the balance of the line.

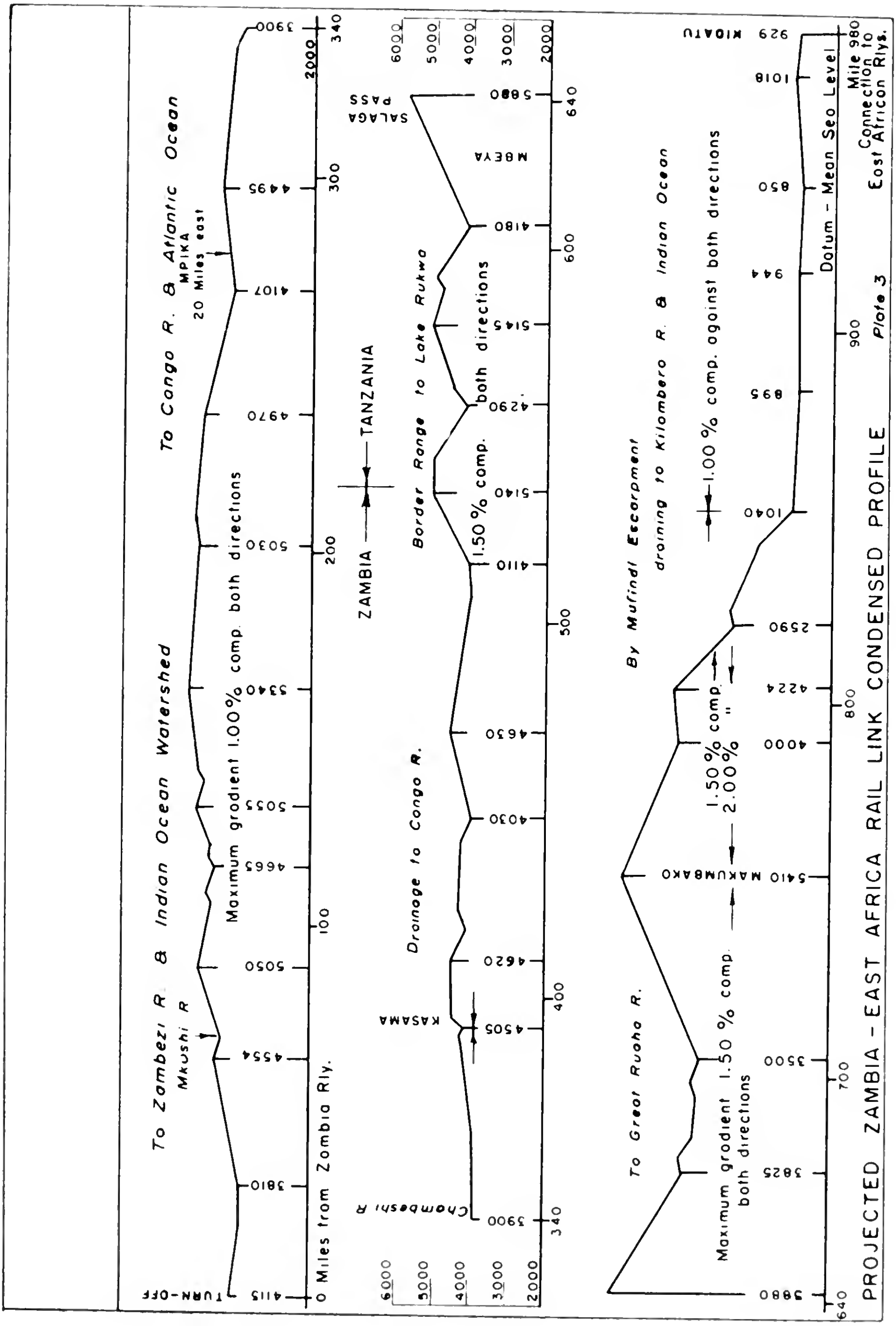
Seasonal water levels and clearances for structures, including highway crossings, also affected the elevations of grades.

Roadway Formation, for Narrow-Gage Railway (3 Ft 6 In)

Embankments, minimum top width 18 ft and slope 1½ to 1, to be increased with respect to heights and classes of soils.

Excavations, bottom width 30 ft with minimum slopes ¼ to 1, to be flattened and/or stepped in relation to depth and soils. Width should be increased if additional materials are required to build embankments within economical hauling distances.

Frequent violent seasonal rains cause the design of interceptor, side and off-take ditches to be of major importance as protection against heavy erosion, particularly in volcanic ash and micaceous soils on steep slopes.


To Zambezi R. & Indian Ocean Watershed
To Congo R. & Atlantic Ocean
Mkushi R
MPIKA
20 Miles east
Maximum gradient 1.00% comp. both directions
TURN-OFF
0 Miles from Zambia Rly.
ZAMBIA
TANZANIA
Drainage to Congo R.
Border Range to Lake Rukwa
1.50% comp.
both directions
Chambeshi R
KASAMA
MBEYA
SALAGA PASS
To Great Ruaha R.
By Mufindi Escarpment draining to Kilombero R. & Indian Ocean
Maximum gradient 1.50% comp. both directions
1.50% comp.
2.00% "
1.00% comp. against both directions
MAKUMBAKO
KIDATU
Datum - Mean Sea Level
Mile 980 Connection to East African Rlys.
Plate 3
PROJECTED ZAMBIA - EAST AFRICA RAIL LINK CONDENSED PROFILE

MAJOR FEATURES OF THE LINE AS PROJECTED

Distances

(a) The air-line distance from the existing railway in Zambia, near Kampoyo, to connect with the terminus of the East African Railways' branch line at Kidatu is approximately 710 miles. The length of this proposed "Link," as now projected, is 980 miles.

This is designed together with 7 divisional yards and 86 intermediate passing tracks.

This length of main track is believed to be the practical minimum unless negotiations were to be entered into for a right-of-way through the northern tip of the Republic of Malawi, which might effect a comparatively small reduction, but then, the north-west province of Zambia, about Kasama, would not be so well served.

(b) With respect to operations, it is assumed that trains consisting of export copper are to be marshalled at Ndola, for movement through to Dar-es-Salaam—1300 miles.

Curvature

On the projected "Link," Mile 0 to 390, within Zambia, curvature is light. However, approaching Tanzania, and through this country to opposite the Mufindi Escrapment, 410 miles, the number of curves increases, then becomes heavy to descend through 60 miles of extremely rugged terrain, to the Kilombero Valley. Through the Kilombero Valley, 120 miles, curvature is light. Of the total length of main track, 27 percent is on curves.

Rise and Fall

The drainage pattern causes many differences in elevations to be overcome. Major ascents and descents amount to 15,272 ft and 18,458 ft, respectively, as shown on Plate 3.

CONSTRUCTION ITEMS

Right-of-Way Clearing

On the "Highlands," through which 77 percent of the "Link" is located, forest cover is of medium-size deciduous trees of many species, with light underbrush. This is broken with extensive areas of park-like country and of local cultivation; also, in depressions there are natural grass meadows.

Descending below Mufindi—across the Mpanga River and its tributaries—to the Kilombero Valley, there is typical tropical cover, including dense elephant grass up to 10 ft high.

Grading

Through northern Zambia, 536 miles, as described earlier, soils are generally favorable and only three short sections present heavy works:

Mile 120 to 140—Through rugged rock hills about Serenje.

Mile 163 to 166—Rock ridge near Kanona.

Mile 393 to 400—Rock ridge near Kasama.

On entering Tanzania, much heavier work is obvious for 330 miles; however, on the final 114 miles in the Kilombero Valley, grading will be moderate, Many excavations, up to 100 ft deep, and embankments, up to 100 ft high, are encountered on four sections:

Mile 545 to 555—Descent from the Zambia–Tanzania Border, on steep sidehill; however, soils, including some rock are favorable.

Mile 602 to 667—Near Mbozi to the Songwe River.

Mile 642 to 672—Descent from Salaga Pass on slopes of Poroto Mountains; extremely heavy works are confronted in difficult soils. One tunnel may be advisable.

Mile 800 to 854—Opposite Mufindi Escarpment, across the Mpanga River to Mgawsi, conditions may be critical where deep excavations and high embankments in silty micaceous soils are unavoidable with any practical railway alignment. Tunnels are indicated at four points.

Bridges and Culverts

On account of frequent, sudden, and violent run-offs during the rainy season, through soils subject to heavy erosion, ample openings should be provided through the railway formations to effect quick direct drainage from the right-of-way. Structures should be designed to have ample capacity for maximum flows and velocities under conditions prevailing.

This proposed line crosses only one major river, the Chambeshi, at Mile 343. It has a wide range of water levels and relative widths. Length of bridge should not be less than 630 ft—say six 105-ft spans. Foundation conditions are limestone at no great depth, and height of the structure would be moderate.

However, there are many deep ravines to be crossed which carry run-offs too heavy to be accommodated by culverts. Such crossings require 17 steel viaducts, of heights up to 190 ft, amounting to 8770 ft.

Smaller railway bridges number 87, aggregating 11,755 ft; and 5 highway bridges are required for grade separations.

It is therefore seen that almost four miles of bridges are called for.

Corrugated iron and structural steel pipe and arch-type culverts are recommended for ease of transportation and assembly.

Track Structure

For ballast, it will be necessary to quarry and crush rock. Outcrops of suitable material are obtainable within reasonable hauling distances. In some areas, lateritic material may be used for sub-ballast .

Ties in Zambia are treated timber; steel ties, 6 ft 6 in, are standard on the East African Railways.

Rails in weights of 90 to 95 lb are being adopted for main-line construction and relay.

Signals and Communications

The existing line—between Ndola and Lusaka, Zambia, from which the "Link" would turn off—is operated by CTC; however, it would not appear that this would be necessary, at least for some years, on the proposed line. Communication lines are carried on steel poles.

SUMMARY

This proposed "Rail Link" presents a major challenge to over-all economy of location, construction, operation and maintenance—980 miles is a long distance.

However, it is to connect two existing railways and there is a good highway near much of the route, so access is convenient to permit commencement of construction from the termini and at several intermediate points. The climate and soils would permit construction to be carried on throughout the seasons, excepting opposite the Mufindi Escarpment and through the Kilombero Valley where grading might not be practicable during the rainy season.

On 140 miles, very heavy grading is unavoidable, through the extremely difficult sections, with adverse soils conditions, on the slopes of Poroto Mountains east of Mbeya and through the "jumbled-up" area east of Makumbako descending to the Kilombero Valley.

Bridging presents no unusual features, although several high steel viaducts are indicated.

Buildings—stations, shops and facilities—required on the "Link" will amount to a considerable item. On existing lines, buildings are impressive; for example, the station at Lusaka is of modern-type practical architecture, and at Nairobi, Kenya, the headquarters of East African Railways and Harbours is a fine example of old-style colonial design with respect to climate close to the equator.

Maintenance-of-way—providing drainage is given special attention and bridge and culvert ends, also ditches, are stepped with ample rip-rap—will be normal on 90 percent of the line, but on the other 10 percent, east of Mbeya and by Mufindi, special attention will be required for many years to combat erosion and slides.

The district engineer responsible for maintenance of the East African Railways, out from Dar-es-Salaam, mentioned two local features:

(1) "Black cotton" soil said to defy almost all efforts of compaction.

(2) Damage to railway slopes by elephants and buffalo.

The difference in track gages between lines in Zambia and southerly, and the East African Railways in Tanzania, Kenya, and Uganda, presents a costly operating item for transfer of freight, or heavy additional capital expenditure to convert the East African branch line between Kidatu to Kilosa and its central line, into Dar-es-Salaam, together 244 miles, to 3-ft 6-in gage; also, for relative motive power and rolling stock. The latter, as well as extensive betterment programs, have been under study by the East African Railways & Harbours for some time.

In either situation, additional traffic delivered from the "Link" to E.A.R. & H. would demand improvements to the formation, bridges and track on the existing lines—Kidatu—Kilosa—Dar-es-Salaam.

It is expected that the principal commodity, copper, for export from Zambia, would be diverted from the existing route through Rhodesia and Mozambique, to the African-controlled port of Dar-es-Salaam, Tanzania. Dar-es-Salaam's harbor is well protected by nature. It is reported that, although port facilities are presently limited, it would be practicable to expand to meet future increase in volume of traffic. Other commodities are mostly agricultural, such as maize, tobacco, coffee and tea. Heavy imports are coal and petroleum products.

Estimates of capital cost to construct the 980 miles of proposed railway from Kampoyo to Kidatu, together with expenditures to change the gage and improve the East African Railway on through Kilosa to Dar-es-Salaam; to expand port facilities; and to purchase equipment required to put the project into operation

have been submitted, from London, to the Inter-Governmental Committee, along with estimates of annual expenditures of maintenance of way and operation and of revenues.

In summary, it is stated, "We believe the railway is a feasible and economic proposition. The net additional cost compared with other means of providing the transport facilities which will be required over the next two decades is not all that great compared with the development and political advantages which will accrue to the two countries (Zambia and Tanzania) from building Zambia, East Africa Rail Link."

A report from Lusaka, July 4, 1967, is interesting—"China has agreed to finance and build a planned $300,000,000 railway between Zambia and Tanzania, President Kaunda of Zambia told a press conference Wednesday. He said that before a final decision is taken, replies from four countries approached for aid for the railway—the United States, Britain, France and Japan—will be examined."

ACKNOWLEDGMENT

The feasibility study of the proposed Rail Link and relative facilities was carried out by a consortium of economists and engineers—Maxwell Stamp Associates Limited, Sumption Berkeley & Company Limited, and Livesey & Henderson of London, England, and Canadian Aero Service Limited of Ottawa, Canada.

The author of this paper expresses his appreciation of being appointed chief engineer for the railway location project and for the generous provision of personnel, equipment and accommodations to facilitate the work. He extends his thanks for the very helpful cooperation received from all members of the British–Canadian survey team in the field and in the office; also, to Dr. Ta Liang, of Cornell University, specialist in air photo interpretation and tropical soils, to Government Officials of Zambia and Tanzania, and to Engineers of Rhodesia Railways and East African Railways & Harbours who gave so unstintingly of their extensive personal experiences with respect to railways in East Africa.

Advance Report of the Special Committee on Systems Engineering

L. P. Diamond, *Chairman*

Computer Service by Time-Sharing

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INTRODUCTION

The life of almost every person is touched at frequent intervals by electronic digital computers. They are used for a multitude of purposes from the checking of income-tax returns to the maintenance of mailing lists. In the business world, computers are used for maintaining inventories, handling payrolls and generating statistical reports on business operations. In the scientific and engineering field, computers are used for analyzing research data and for performing tedious and time-consuming calculations in analysis and design. Tasks are being performed which would be utterly impractical by hand or even with the aid of desk calculators. If enough calculator operators could be organized to keep the total time for these tasks to an acceptable figure, the frequency of human errors probably would make the results useless.

Counterparts of most of the applications suggested above are found in the field of railway transportation, where computers are used for a variety of purposes, such as:

1. Payrolls
2. Freight car records and tracing
3. Freight bill preparation
4. Equipment assignment and use records
5. Inventories of supplies
6. Reservation systems
7. Engineering calculations

Although computers are used today in many different phases of railway engineering and operation, there is great potential for increased use. Lack of convenient access to a computer is probably the main hindrance to more widespread use. However, if the time-sharing concept is applied, the computer may be made readily available to the people in the various departments of a railroad who need its capabilities.

BASIS OF COMPUTER TIME-SHARING

In general the most economical and versatile computing installation is obtained by concentrating available funds on a single, large computer rather than allocating them among a number of smaller computers. Most efficient operation of a computer is accomplished by making available a continuous stream of calculation jobs for processing. This type of operation is called "batch processing." With this scheme of operation, the time from job submission until the output is available may be from an hour to several days. Obviously, this arrangement limits the use of the computer to problems in which delays of this magnitude can be tolerated. In cases where such delays cannot be tolerated usable results, but probably less accurate, can be produced by hand or other means in less time. Batch processing also hinders severely any interaction between man and machine in which the results of one set of calculations are assessed in developing data for a subsequent set of computations.

If each individual is to make the greatest possible use of a computer in his work, a computer must be available to him when he needs it. This can be done most simply by providing a small computer for each individual who can use one effectively. But, as mentioned previously, a smaller total computing capacity can be expected by spending available funds on a number of small computers instead of spending them on a single large computer. The processing of some problems may also prove very inconvenient or even impractical on small computers because of storage and speed limitations. With assignment of computers to individuals, much less efficient operation can be expected, because the continuous flow of jobs characteristic of batch processing is not practical.

The combined advantages of a single large computer installation and essentially immediate access to a computer for each individual user can be achieved by a scheme called "time-sharing." This scheme is based on the observation that a user, with unrestricted access to a computer, usually can use the computer for actual computation only a small fraction of the total time the computer is available to him. The remaining time is spent in analyzing the problem, supplying information to the computer and reviewing the output produced by it. However, if the computer is to be of greatest value to the user, these small segments of on-line time must be available to him almost immediately upon request.

A computer time-sharing system consists of a number of remote input-output terminals and a central computer facility arranged to allocate computer time to each connected terminal at sufficiently short time intervals to give each user the impression of exclusive control of a computer. The remote input-output devices may be teleprinters or more complicated devices such as card readers, line printers, or cathode-ray tube display devices. The remote terminals are connected to the central computing facility by telephone lines or other communication links. The central computer facility and all remote terminals associated with it may be located within a single plant for the exclusive use of the personnel of one organization. In other cases, one organization may provide the central computing facility and offer the services to a wide variety of users located in many different parts of the country, or even in other countries.

TIME-SHARING OPERATION

A computer time-sharing system probably can be understood best by describing it from the viewpoint of a user who has a remote terminal in his office, such as the common typewriter input and output consoles. Basically these units perform the same function as the teleprinters used for communication purposes. They are equipped with four-row keyboards instead of the three-row keyboards usually found on communication teleprinters. This makes possible more convenient typing and a larger number of characters. Transmission usually is accomplished over telephone circuits at a nominal speed of 100 words per minute, using the 8-level American Standard Code for Information Interchange (ASCII). Transmission of telegraph signals over conventional telephone circuits requires a special device which contains auxiliary equipment for generating and detecting the required tone signals. Usually the tone equipment is physically connected to the telephone line, but equipment is available for acoustic or magnetic coupling of tone signals to any telephone.

Assume the user, an engineer, has a problem to be solved. It may be as simple as computing the three angles of a triangle given the lengths of the three sides, or it may be vastly more complicated. The engineer is assumed to have in mind, or preferably to have written down, the steps for solving the problem in a language available to him through the time-sharing system being used. This language may be a procedure-oriented language such as FORTRAN, BASIC, ALGOL or MAD. These make possible readable but unequivocal communication of mathematical procedures on mechanical devices such as typewriters, teleprinters and punched-card equipment. In the case of problems in a particular area, problem-oriented languages such as COGO for geometric problems and STRESS for structural analysis problems may be available.

The engineer uses the telephone associated with the transmission equipment to place a call in the normal manner to the computer, either by dialing local or long distance or through the assistance of an operator. The call is answered automatically by the computer as indicated by a tone signal. At this point, connection is transferred to the teleprinter. Subsequent communication with the computer is by means of the keyboard. The steps for initiating time-sharing system operation depends on the particular time-sharing service being used. Usually this consists of typing a specified code word. At this point, the computer may cause the typing of a series of questions. For each question, a valid answer must be typed by the user. The questions may ask for the user's account number, a confidential password to prevent unauthorized usage; the name of the programming language which the user intends to use; and whether he intends to write a new program or use an old one which he has previously stored in the central computer facility. If the user specifies that he intends to write a new program, he then proceeds to type the new program on the teleprinter. Usually a time-sharing computing facility includes extensive programs for editing of information stored in the facility. This makes possible correction of typing mistakes either as they occur or later in reviewing the typed copy. The editing facilities also make possible the modification of new or old programs as required. The modified or corrected program may also be typed out in its entirety or in parts for proof reading and verification of corrections or modifications.

After the user is satisfied that his program is stored correctly in the computer facility, he requests execution of the program. The program may require data on which to base calculations. These may have been stored with the program, or the user may supply them through the keyboard as required by the program. As execution proceeds, output will be produced by the teleprinter in accordance with the instructions contained in the program.

If the program is a new one, the user can request the opening of a new file for the storage of the program for later use. Programs previously stored can be eliminated also, if no longer needed, to make room for new programs.

When all the desired computations have been completed, the user initiates a sign-off procedure. This action causes termination of time charges and disconnection of the telephone circuit.

TIME-SHARING COSTS

Computer time-sharing costs usually can be broken down into three components:

1. Time-sharing service cost
2. Remote terminal cost
3. Long distance telephone service cost

The schemes used in establishing charges for time-sharing service varies from organization to organization. Charges usually are based on some combination of charges from the following categories:

1. Service initiation charge
2. Charges based on the time the remote terminal is connected to the central computing facility.
3. Charges based on the time the central computer is engaged in servicing the user. This time is typically a very small fraction of the total remote terminal connection time.
4. Charge based on the amount of storage occupied by the user's program library.

Some suppliers of time-sharing service make a service initiation charge while others do not. A typical service initiation charge is $100.

For remote terminal connection time there is usually a minimum monthly charge which allows specified amounts of remote terminal connection time, central computer time and storage. Services are offered with very low or no minimum monthly charge, but more typical charges are $350 for 25 hours of connection time and appropriate amounts of central computer time and storage. Above 25 hours per month the rate for remote terminal connection time is of the order of $9 to $10 per hour.

The minimum remote terminal cost, including the transmission equipment and telephone connection, is approximately $75 per month. Installation charges for this equipment amount to approximately $60.

Long distance telephone charges will vary depending on the distance of the user from the central computing facility. If the time-sharing computer is located in the user's local calling area, there will be no additional charge in this category. In some cases suppliers of time-sharing service provide foreign exchange lines to particular cities in order to make their service available by local telephone calls in these cities. If long distance charges are involved, the charges in this category may be in the range of $10 to $30 per hour. If usage is heavy, foreign exchange (FX) service, wide area telephone service (WATS) or private leased wire service may be more economical than toll service.

In order to make estimates of the total expected monthly cost of time-sharing service, some assumptions must be made concerning usage patterns and location relative to the central computing facility. Cost estimates will be made for two examples. If the central computing facility is available for a local telephone call, the total monthly cost, assuming one hour of terminal connection time during the month, can be approximated as follows:

Terminal connection time—1 hr at $40/hr	$ 40
Transmission equipment and local phone service	75
Total monthly cost	$115

If the usage is 25 hours per month and the location is approximately 120 miles from the central computer facility, the approximate charges will be:

Terminal connection time of 25 hr	$350
Transmission equipment and local phone service	75
Long distance charges—25 hr at $12/hr	300
Total monthly cost	$725

The above estimates are based on using the services of a time-sharing service organization which offers its services to the public. Time-sharing systems can be operated by a single company for servicing terminals located within its own plants or offices. In the latter case, the cost would depend on the company's experience in providing computer and communication services and the practices used in allocating costs associated with these services.

UNIQUE ADVANTAGES OF TIME-SHARING

Up to this point time-sharing has been discussed from the viewpoint of providing readily available computer service to each individual who has a need for this service. As has been mentioned previously, this need could be met by providing computers for each individual. The choice is primarily a matter of economy—can the computing needs of each individual be met more economically by a time-sharing terminal with the accompanying communication costs or by the installation of a small computer?

There are situations in which time-sharing offers unique advantages. For example, an individual who has occasional need for a high-speed computer or a computer with a large amount of storage. In such a case the cost of a satisfactory computer for the individual probably would prove prohibitive. But, by time-sharing a central computer the user can obtain high speed and large storage capacity at a relatively modest cost.

Another situation in which time-sharing offers a major advantage occurs when many people must have essentially simultaneous access to common data. The function of some of the people must be to keep the data up to date, and some may be involved both in updating and using the data. One example of this usage is found in the handling of passenger space reservations. People in many different offices need information on available space and must record space assignment when a reservation is made. The time-sharing principle also has been used in connection with clearing high-wide loads for movement over the lines of a railroad. Data on clearance restrictions may be stored in a central computer for immediate availability to those individuals located at many points on the railway system charged with making decisions on load acceptance and routing.

The above examples have illustrated opportunities for interaction between the user and the computer in which the information, computations and action requested from the computer could be determined on the basis of information previously received from the computer and reviewed by the user. This possibility of interaction between the engineer and the computer offers many challenging opportunities for making use of the engineer and the machine in the way in which each functions best. The routine calculations and decisions can be made very rapidly and accurately by the machine. The engineer on the other hand can supply the judgment and intuition required in those situations which are not subject to formulation. With the machine to do the laborious and monotonous tasks, the engineer can devote his full efforts to creative work. A part of this creative work can be the devising of better methods and procedures for solving the problems which he encounters.

Time-sharing also offers advantages during the early stages of applying a computer to the work of an engineering department. At that time the personnel usually are not in a position to fully utilize a computer which has the storage and speed eventually needed by them. By using the services of a time-sharing organization, computing facilities can be provided without the high fixed costs which would accompany a computer installation. Later, as experience is gained in applying digital computers to their work and after a library of production programs has been built up, the cost of the computer installation may be justified easily.

CONCLUSIONS

The time-sharing principle makes it economically feasible for each individual who can productively use a digital computer to have convenient and essentially instantaneous access to one. Reduction of the elapsed time between problem submission and return of results increases the number of problems on which a computer can be used in any given period of time. Time-sharing also makes it possible for a number of people to use information from a common storage facility. Easy and convenient access to a computer makes possible the man-machine interaction necessary for full utilization of both the man and machine.

Advance Report of the Special Committee on Systems Engineering

L. P. Diamond, *Chairman*

Project HISTEP

By P. W. LINDGREN
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INTRODUCTION

The Office of High Speed Ground Transportation of the U. S. Department of Transportation awarded a number of months ago a contract to Melpar, Inc., a subsidiary of Westinghouse Air Brake Co. (WABCO), of Falls Church, Va., to provide support services for a high-speed train evaluation program (HISTEP). Included in the contract are the acquisition and installation of instrumentation; collection of data necessary for an evaluation of the problems associated with high-speed rail transportation, with particular emphasis placed on its effect on passenger comfort; development of the necessary data reduction computer programs; and the formulation of a general simulation program that will be used in the analysis of proposed design changes.

Four research cars manufactured by the Budd Company have been used in the testing program. The cars were designed so that minimum effort would be required to install the instrumentation and associated electronics, as well as to achieve speeds in excess of 150 mph. The cars, which are electrically powered, have exceeded this speed several times in tests conducted during 1967.

The Pennsylvania Railroad has done extensive work on a 21-mile section of track between Trenton and New Brunswick, N. J., in order to ensure optimum track conditions for the tests. All high-speed testing will be conducted on this test section. In addition, track profile measurements will be made of various tracks between Washington and Boston, and other sections of track as designated by the Department of Transportation.

The parametric evaluation of the various phenomena which are intrinsic to train operation and performance are of particular interest. These include jerk, acceleration, vibration, motion of the car, noise level, truck performance, pantograph and catenary performance, train interaction, track performance under different loadings and any others that evolve during the conduct of the program.

The purpose of this paper is to describe some of the methods and instruments used to collect the data, and the data reduction programs that have been or will be developed to reduce the data to useful engineering form. The brevity of the article has been dictated by space limitations .

The data being collected are, for the most part, multiplexed and recorded on magnetic tape utilizing an AMPEX FR 1300 recorder. The magnetic tape speed is set at 30 in per sec; however, the tape speed can be varied over a wide range. In addition to the magnetic tape recordings, closed circuit television (CCTV) is used to monitor pantograph motion, wheel-rail interaction, and catenary motion. Also, it is possible to record eight channels of data on a Brush Company direct recording oscillograph during the running of various tests.

Of the four research cars, only T1, T2, and T4 have been instrumented. Each of these cars has a motor generator set installed to serve as a power supply for the instrumentation and recording equipment. Car T1 is used to collect electrical-system data and to observe pantograph-catenary interactions at various speeds. These measurements include pantograph motions, as well as operating temperatures, voltages and currents. A closed-circuit TV system is used to monitor pantograph motions and arcing under different conditions of consist and speed. In addition, new pantograph designs will be installed and tested on this car.

Car T2 has been instrumented primarily to measure track geometry. This includes such measurements as rail alignment, gage, cross-level and profile. In addition, this car will be used to generate such key information as distance, speed, time, and location, to which other data are referenced, as well as to carry the recording equipment for all measurements except the wayside recordings.

Car T4 has been instrumented to furnish ride quality and truck performance data. To accomplish this, accelerometers will measure the accelerations along the three perpendicular axes in the passengers' compartment and on the trucks themselves. Also, vibrations and noise levels will be recorded as well as air pressure effects when other trains are passed and when passing wayside stations. In addition, several other parameters relevant to wheel-rail interactions will be recorded and observed visually through the use of closed-circuit TV.

Car T3 is a back-up car and at present has no instrumentation installed. However, it is contemplated that it will be used for special performance tasks to be determined as the program evolves. One such test recently completed included the installation and evaluation of telecommunication equipment.

A wayside instrumentation package is currently being developed. Its purpose will be to collect roadbed dynamics data during train passage and to measure the effects that repeated loadings have on the roadbed. TV monitoring of the catenary is also included in the wayside instrumentation package. Of particular importance is the fact that operation of the wayside instruments will be synchronized with those of the test cars. In addition, the wayside package, as well as the car instrumentation, will be semi-portable so that relocation will require a minimum of effort.

The type of performance data measurements and the location of the required instrumentation is shown in Table 1. Tables 2 through 4 give a more detailed breakdown of the type of sensors which have been installed on the various research cars.

DATA REDUCTION

As previously mentioned, the majority of data is recorded on magnetic tape. This has required that the data be digitized prior to reducing the data to useful engineering information. This digitizing is accomplished by utilizing what has been designated the pass 1 data reduction program. A special item which was installed in the DDP 224 computer for Project HISTEP is the direct memory access. This enables the computer to fill a block of memory while dumping a block of memory to one of three magnetic tape units. This cyclic action continues until the complete analog tape has been digitized. A manual event, designated tape transfer, which indicates the end of data, is recorded on the timing track of the tape. The program looks for this input during each loop of the program. When this transfer pulse is found, the computer outputs a message to the typewriter and goes into a waiting loop. The pass 1 program can be terminated at this time or additional analog tapes can be processed.

TABLE 1 PERFORMANCE PACKAGES	
Description	Location
Pantograph Performance	T1
Visual Motion (CCTV)	T1
Track Geometry	T2
Recording Instruments	T2
Monitoring	T2
Experimental Systems	T3
Car-Body Motion	T4
Vibration and Sound	T4
Truck Performance	T4
Truck Motion	T4
Wheel Rail Visual (CCTV)	T4
Train Interaction	T4

The data, after being digitized, are then processed by means of pass 2 programs. These programs have been developed to satisfy certain program objectives. They include the Ride Quality Program, Truck Performance Program, Electrical Performance Program, Wheel Slip and Slide Program, Wayside Program, and Dynamic Track Geometry Program. In addition to the above programs, special subroutines have been written which help the engineers in their analysis of the data. These include the histogram, spectrum, maximum, minimum, mean, and RMS subroutines. The root mean square (RMS) value is calculated by the following formula:

$$\text{RMS} = \sqrt{\frac{\sum_{1}^{N} f(n)^2 - \text{mean}^2}{N}}$$

where: N = Total number of samples
$f(n)$ = Value of individual sample
mean = Average value of the N samples

The RMS is analogous to the statistical term Standard Deviation. In addition, a special plot routine has been developed which enables the user to plot up to five selected variables on the line printer. However, usage of this routine has shown that when five variables are printed, interpretation of the results becomes quite difficult. This is particularly true when their values are quite close. An additional routine, which has proved quite valuable when computer availability is restricted, is the dump/fill routine. This enables the program user to dump the entire core on magnetic tape. He only has to reload the tape into the computer when it is next available to restart at the same point in time.

TABLE 2

T1 PERFORMANCE MEASUREMENTS

Electrical Performance	Data Generated
Closed Circuit TV	Pantograph Motion and Arcing
Wattmeter and Power Converter	Power
Kilowatt Hour Meter	Power Consumption
Main Transformer Connection	Pantograph Voltage
Current Transformer Connection	Pantograph Currents, Dis-connects
Arc Detection Coil	Arc Events
Displacement Transducer	Pantograph Height
Accelerometers	Pantograph Shoe Accelerations

TABLE 3

T2 PERFORMANCE MEASUREMENTS

Track Geometry	Data Generated
Vertical Gyroscope	Cross Level and Warp
Proximity Sensors	Surface, Alignment, Gauge
Displacement Sensors	Catenary Height
Accelerometers	G-Loadings
Speed Sensor & Odometer	Speed and Distance
Impedance Bond Detector	Impedance Bonds, Grade Crossings, etc.
Manual Switches	Initializing, Mileposts, Track #, etc.
CCTV Cameras	Visual Motion Monitoring

TABLE 4

T4 PERFORMANCE MEASUREMENTS

Car and Truck Performance	Data Generated
Accelerometers	Car Body Linear & Angular Accelerations
Vibration Level Meter	Vibration Levels
Sound Level Meter	Sound Levels
Displacement Transducers	Car Body Motion - Coupler Displacement
Strain Gauge	Draft-Gear Force
Accelerometers	Journal Bearing & Sideframe Vertical and Lateral G's; Truck Bolster Vertical and Roll Accelerations
Displacement Transducers	Car-Truck Lateral Motion, Truck Yaw
Strain Gauges	Sideframe Bending; Truck Stresses
Pressure Pickups	Brake Cylinder Pressures
Current Measurement Connector	Motor Current and Torque
Wheel Speed Sensors	Train Speed, Slipping & Sliding
Pyrometer	Wheel Tread Temperature
Pressure Pickups	Lateral and Internal Car Pressure

The types of data that the various programs generate are given in Tables 2 to 4, which were cited in a previous paragraph. It should be pointed out also that, in addition to the engineering analysis data which these programs provide, other special options have been included which permit the user to output data for use in validating the generalized simulation program.

The author presented a paper entitled "Dynamic Train Simulation" at the 22nd Annual Instrument Society of America Conference which was held Sept. 11–14, 1967 in Chicago. This paper went into a more detailed discussion of the simulation program which has been developed by Melpar. However, a few highlights of the simulation program are discussed below to give the reader an insight into its purpose.

The program represents a generalized mathematical model composed of 15 members, each having 6 degrees of freedom. Minor reprogramming will allow an increase in the number of members; however, a penalty of increased program execution time results. The model is "run" over actual track profile data or over an equivalent statistically generated track. The various forces, moments, angular rates, displacements, etc., of selected members can be outputted along with their appropriate statistics (maximum, minimum, mean, etc.). These results are compared with data generated during the test series for purposes of model verification. Where discrepancies exist, appropriate modifications are effected.

CONCLUSION

There are many problems associated with railroad operation and analysis which lend themselves readily to solution by digital computation. It was not the intent of this paper to present data and results, but rather to outline some of the techniques and applications developed by Melpar. The responsibility for publishing the results of the testing series rests with the Office of High Speed Ground Transportation. I am quite sure that we can all look forward to a series of meaningful and useful documents which will give us an insight into the present-day problems, possible solutions, and an informed look into future railroad operations.

Organization of Railway Engineering Departments

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PURPOSE

This paper discusses, from an administrative point of view, the organization of railway engineering departments.

Readers are assumed to be mostly engineers employed by railroads.

It is hoped to provide them with a view of practices in a number of companies other than their own, indicate various ways the activities of these departments can be organized, and stimulate thought about the management of railway engineering.

Many railway company managements have had their organizations analyzed in recent years by outside consultants or by their internal staffs. These studies rarely become available to others. Little research unrelated to immediate management objectives or comparing several companies appears to have been conducted. Such material is sparse in the professional literature. This paper is intended to help to fill this information gap.

CONTEXT

This is a summary of an extensive research project, conducted in seven railroad companies, with the assistance of their managements.[1]

Three separate papers, each on a different topic, report the findings. The career development of graduate engineers employed by railroads has been discussed in an earlier publication of AREA.[2] A current article in another journal is devoted to an appraisal of the effectiveness of adjustment to technological change by engineering departments.[3] This paper is the third and presumably last of the series.

STRUCTURE OF THIS PAPER

The plan and procedure that were used are briefly described. The data and most of the detailed analyses, included in the complete study, are omitted herein. The findings and conclusions, followed by related opinions and suggestions, are presented in a condensed manner.

Individual companies are not identified in this paper.

The past tense used best describes what was actually observed when the data were gathered while at the same time it avoids implying that any specific detail is or is not currently still true.

STRUCTURE OF THE TOTAL RESEARCH PROJECT

This project had a classical scientific research design, an exploratory orientation, and an administrative point of view.

Data were collected over a 6 year period, in 7 railroad companies, with the cooperation and assistance of their managements. There were over 200 personal interviews in 25 geographic locations. Many company documents, such as organization charts and manuals, position descriptions, company correspondence, management directives, engineering instructions, personnel records, and similar sources, were reviewed. This material was condensed, organized, and presented in the form of 7 descriptive cases, with a combined length of 448 pages, including 56 organization charts. Many other companies were looked at briefly.

The analysis was in the form of a series of comparisons of separate aspects of organization. The fixed plant, functions pertaining to it, the role of the engineering departments, their place in each company's total organization, and their organizational and geographic decentralization were considered first. Comparisons followed of the various levels of management; the divisions, districts, regions, and headquarters; with emphasis upon their functions and their organizations.

Five responsibilities of engineering departments were then compared and discussed, primarily in terms of the detailed functions and organizations related to them. These were: maintenance of way, administrative "paper work" and related minor design, signals and communications, structural design, and construction management.

The relationships of industrial engineering, technical research and development, and personnel management to the engineering departments were also considered.

A summary and synthesis were then presented. These led in turn to the development of a number of general conclusions, some with related exceptions. The study concluded with the author's personal opinions.

The study has been completed.[1]

ENVIRONMENT

The fixed plant of all railroads was similar; the major categories were: track, structures, signals, communications, and sometimes electric traction fixed facilities.

A number of functions were always associated with this plant. These included planning, design, construction, and maintenance of the physical facilities. There were also many related administrative tasks, such as, for example, scheduling, capital budgeting, general administration, and personnel development.

"Engineering Departments," in most railroad companies of Class I size, were responsible for the fixed facilities and the functions related to them. These were generally combined with the mechanical and transportation departments into "Operating Departments." Apparently this was less true in the past, when engineering was a separate department in many companies.

The official in charge was usually called the "Chief Engineer." However, occasionally he held the title of assistant vice president or vice president. He most frequently reported to a vice president—operations or a general manager, rather than directly to the president.

Technological changes were affecting not only the fixed plant, but also the functions associated with it, the organizations responsible, and the qualifications of the individuals concerned.

DECENTRALIZATION

The engineering departments, and the operating departments of which they were a part, were usually decentralized, except in some smaller companies. This decentralization was both geographical and organizational in nature.

Geographically, most railroads were subdivided into territories which were generally called divisions.

There had been a strong trend in most companies, underway for over a decade, toward consolidation of divisions into a smaller number of larger ones; as a consequence the average miles of line per division had substantially increased. Officials of some smaller companies were considering moving toward single divisions.

Organizationally, there were typically several echelons or levels of management: a headquarters, general, or system office; the divisions; and in some companies intermediate organizations, usually called regions or districts, interposed between these two. The intermediate levels were more prevelant in companies with longer lines and consequently more numerous divisions; they had jurisdiction over several of them.

Reductions in the number of organizational levels had been less frequent. In one very large company a drastic reduction in the number of divisions concurrently made it possible to reduce four levels to three. There was talk on several railroads of reducing the number of levels from three to two, by enlarging divisions still further, thus reducing their number, and then eliminating the regions or districts. The single division railroad would automatically do away entirely with the different levels.

Organizational changes were being facilitated by technological ones. Some resulted in less need for supervision and others made supervision possible over much larger territories.

ORGANIZATIONAL RELATIONSHIPS BETWEEN ENGINEERING OFFICIALS

The formal organizational relationships between engineering officials at headquarters and those in geographically and organizationally decentralized division, area, district, and regional offices were in either departmental or line-staff patterns. One hybrid of the two was observed.

In a departmental organization, engineering officials in charge of lower level engineering forces (such as division engineers) reported directly to other engineering officials (such as the engineer of maintenance or the chief engineer) at higher levels, while they maintained liaison with non-engineering operating officials (such as division superintendents) at their own level. In a line-staff type of organization, engineering officials (such as division engineers) reported directly to non-engineering operating officials (such as division superintendents) at their own organizational level, and at the same time had indirect or staff relationships with engineering officials (such as the engineer of maintenance or the chief engineer) at the next higher organizational level.

Departmental engineering organizations were much more common in the past. They were similar in many ways to the army organizations of an earlier era. One can speculate whether the fact that railroads were the first large-scale geographically decentralized civilian enterprises engaged in operations involving an advanced technology meant that military organizational concepts were the only ones available to use as precedents. A number of engineering officials in several companies expressed their preferences for this arrangement.

Line-staff relationships were formally in effect in most of the companies studied. Many people explained that this organizational pattern was more desirable, as it focused all operating responsibilities for a geographic portion of the railroad upon one official.

Within several of the line-staff engineering organizations there were incorporated formal departmental relationships for one or another group of functions or facilities. Examples included signal and communications forces in some companies and supervision of large construction operations in others. There were also many informal departmental relationships. Some were carry-overs from former ones. The line-staff arrangement often appeared awkward, to either or both lower and higher echelon engineering officers. They had problems trying to get things done through the formal organizations so they developed informal line relationships with each other. They then attempted to keep the operating officials in the formal line relationships informed after the fact. When line superiors were not too interested in a particular function, such as for example signal maintenance, these informal arrangements flourished.

One medium-size company had a fairly workable solution for all this. Most of the engineering and operating officials had such frequent, close, and informal personal contacts with each other that there was much less need for concern as to what the formal organizational patterns were supposed to be. An organization chart had to be developed by the author.

The term "Engineering Department" is normally used within the industry (as well as by the author) to include all the offices and officials within a company responsible for fixed plant facilities and engineering functions. This is a misnomer whenever these offices and officials are in line-staff organizations, only indirectly related to each other.

DISTRIBUTION OF FUNCTIONS WITHIN THE ENGINEERING ORGANIZATIONS

Whenever there was more than one level of organization, engineering activity was usually distributed as follows:

Headquarters

In most companies, headquarters officials were supposed to concentrate upon policy, planning, budgeting, setting standards, general guidance, coordination, scheduling, and so on. They had line management responsibilities only for those functions or facilities organized in a departmental manner. Many of them also concerned themselves with a multitude of small details.

Larger companies had different policies about whether such work as structural design, signal design, inspection of maintenance, or construction supervision should be done at headquarters or at intermediate levels. Some or all office engineering was done at headquarters in some companies while it was additionally done at either or both the intermediate and division levels in others.

Regions and Districts

Intermediate-level offices had more varied duties than the others. They provided liaison between headquarters and divisions about one or more functions or facilities. Sometimes they also had line responsibilities, such as for rail replacement or signal installation. They filled different roles in regard to inspection of maintenance and the supervision of construction. In some companies one or more kinds of design, such as of structures, signals, or communications, were done at these levels.

Divisions

Routine maintenance of fixed plant was the primary function of the divisions. Construction supervision or inspection of maintenance were sometimes assigned to them too. There were wide variations among companies as to the amount and type of office engineering work done here.

Exceptions

Two unusual arrangements were observed. In the new organization of one very large company, the system engineering office was supposed to be concerned with very broad policy, planning, standards, and coordinating functions while the regional offices were to act more like the headquarters of important subsidiaries than like the usual intermediate organizations in other companies. In another large company, for several years some of the usual headquarters functions were moved downward and division functions moved upward; they were combined in the office of the regional engineer to eliminate liaison and duplication.

There was considerable evidence in almost all companies that each level often played more than its assigned role. Headquarters often furnished detailed direction as well as broad guidance; intermediate levels often extended their concept of liaison to also include line management. In only the one company mentioned above did headquarters officials appear to limit themselves largely to policy.

ORGANIZATION OF ENGINEERING OFFICES

Some generalizations and related exceptions applied to the organization of each management level.

Headquarters

There were three principal types of activities.

Some were related to a function, such as developing maintenance methods, engineering design, or preparation of capital budgets.

Some were concerned with a particular category of fixed plant, such as track or signals.

Some were involved with a particular function applied to a particular category of fixed plant, like maintenance methods for track, design of bridges, or AFE preparation for signals.

Some individuals had primarily line responsibilities, most had primarily staff responsibilities, and some had a combination of both.

In addition, there were sometimes several echelons of authority within staff groups working on functions that required a number of people, for example large structural design offices.

Some people were generalists, dealing with a variety of subjects. Others were specialists, often with narrowly defined responsibilities, such as timber preservation.

Several activities were present in all departments, with specialists assigned to them, such as track maintenance, structural design, or office engineering. Most departments had one or more additional specialists concerned with other common subjects, such as communications or architecture. There were still other specialized assignments to be found in fewer engineering departments, such as valuation (often assigned to other departments), electric-traction fixed facilities or fire protection.

There was almost always at least one individual concerned full time with each type of major facility, such as track, structures, signals, and communications.

Specialists in some departments were assigned alone to subject areas that in other departments required two or more people, or were only part of an individual's duties. Examples included water service, grade crossings, soils and foundations, terminals, construction, timber preservation, and electrical and mechanical engineering related to fixed plant.

There were assignments that ranged from one or a few men in some departments up to large staffs in others, for example maintenance of way, structural design, and valuation.

Sometimes a supervisory official reporting to the chief engineer was in charge of several people, each of whom was working on a different specialty. In another company, or even in the same engineering office for other subjects, several individual specialists might all report directly to the chief engineer.

The span of control of chief engineers varied widely. Those observed had as few as three to as many as eleven people reporting directly to them. These spans increased and decreased for the same individual from time to time.

On some organization charts, headquarters personnel were tidily arranged, while on others they were in wide disarray. These charts changed considerably during relatively short periods of time. In some companies there had been several major reorganizations during a ten-year period.

These many differences appeared to result from management planning studies, legacies of past arrangements and practices, and the need to provide continuing positions for certain specific individuals. Senior officials sometimes adjusted formal organizations, including span of control, to suit their own opinions and personalities, in preference to substituting informal relationships for the formal ones.

Regions and Districts

The intermediate-level organizations that were observed were directed by single officials in three companies, while in the fourth there were several engineering officials who each reported concurrently to the two general managers. All included individuals concerned with maintenance of all types of facilities; whose duties and the sizes of whose organizations varied widely. Some acted as staff specialists, others were in charge of active forces working out along the lines. Design, office engineering, and construction groups were included in some organizations but not in all.

Divisions

These engineering forces were all very similar. They were supervised by a division engineer, or equivalent. He was usually preoccupied with track maintenance, both because this was his most costly operation, and also because of constant reminders that this was of particular concern to higher management.

Some companies provided for an assistant division engineer. He was expected to function in one of several ways: sharing management responsibility with the division engineer, as a true assistant to him, or as a specialist, such as for the track program.

Track supervisors in charge of track maintenance and bridge and building supervisors responsible for maintaining structures reported to the division engineers, in all companies that had divisions. Signal and communications supervisors in charge of maintenance of those facilities reported to the division engineers in most companies. They also often had strong unofficial line relationships to signal and communications officials at higher organizational levels. In a few companies the division signal and communications supervisors had formal departmental relationships with signal and communications officials at higher management levels.

There was usually an assistant engineer or office engineer, assisted by a staff, in charge of office engineering.

OTHER ORGANIZATIONS CONCERNED WITH FIXED PLANT

In several companies, other departments, such as technical research and development, industrial engineering, and personnel development, worked on improvements to "hardware", methods, and organization. Their activities, and their relationships to the engineering departments, differed in each company and in each area of mutual concern. Sometimes working relationships were close, and included exchanges of personnel; in other cases the interaction was more formal and infrequent.

In addition, most engineering departments also had individuals or groups assigned to such duties. However, these people often lacked the particular professional training and the specialized facilities required for maximum effectiveness in such work.

ORGANIZATION FOR SPECIALIZED FUNCTIONS AND FACILITIES

As noted earlier, a number of specialized functions and facilities were examined in detail and then compared as to similarities and differences between companies, in terms of organizational implications. Several are discussed herein.

Track Maintenance

Routine maintenance of track was always a division responsibility.

Such technological changes affecting track as installation of welded rail and mechanized tie and ballast replacement required expensive machinery and specialized gangs, often beyond the needs of any single division.

New organizational arrangements were developing for this work. In some companies the equipment and manpower were temporarily assigned to division officials. In others, regional, district, or headquarters officials kept primary line responsibility. As a third alternative, division officials were said to be in charge, while in fact the large amount of staff guidance by higher officials meant that they were in effective control.

Bridge and Building Maintenance

Mechanization and methods improvements for bridge and building maintenance were developing more slowly than for track. This was because structures were far less standardized; also because the dollar cost of this work was less. Therefore changes affecting track had been given a higher priority by management.

As with track, new developments would affect the duties of the individual supervisors to whom the work was assigned, and this could be expected in turn to affect organization.

Inspection

Practices varied between companies as to which organizational level and which functional group should be responsible for inspection of track, or of bridges and buildings.

Some felt that inspectors should report to division maintenance supervisors responsible for the condition of the plant, as this would facilitate close coordination and fast action on repairs. Others said this compromised inspectors' candor, as they would thus be criticizing the work of their own superior. Some placed the inspectors on a division staff to improve control of the work of the supervisors; however, here they were often also used as extra manpower for many other purposes. Others thought inspectors should be at a higher organizational level, where they could be more independent of view and also help provide quality control of division work.

Inspection of bridges by structural designers, a practice in some departments, was supposed to make these men more aware of the future maintenance implications of their designs, as well as help them to design repairs because they would be personally familiar with conditions out on line.

Office Engineering

In all companies there was a miscellaneous collection of duties and responsibilities, dealing with a wide variety of subjects, usually requiring preparation of large quantities of "paperwork". It is difficult to define or describe them briefly. Anyone familiar with railway engineering will recognize them as tasks of many division office engineers or assistant engineers, as well as their counterparts at district, regional, and headquarters levels. There does not appear to be a generally accepted industry word that includes them all; the author has chosen to call this work "office engineering".

In some departments, all offices at all levels were not only doing office engineering but were also involved in constant liaison about it.

Other organizations had taken positive steps to reduce some of the work, some of the liaison, or both. Only a few examples are mentioned. In one company as much as possible was centralized in the regional engineers' offices. In another the valuation group at headquarters prepared all AFEs with other offices directed to use a simplified standard estimating procedure. In a third AFEs were not prepared until after projects were completed, using numbers derived from the accounting system; they were needed only for the valuation records. One headquarters emphasized a "management by exception" concept. It delegated responsibility to regional officials to act within policy guidelines, retaining concern only for large or unusual cases; this reduced interoffice liaison. Another department seemed to have a novel approach—it was making a major effort to avoid letting many matters get on paper at all.

These different practices created different requirements at different organizational levels for staffs, their sizes, their duties, and the relationships among them.

Communications

Communications organizations were adjusting to accelerating technological changes. Simple telegraph and telephone installations using pole lines alongside the tracks were being superceded by complex equipment. These required large numbers of high-quality channels, often provided by microwave systems, with facilities sometimes located many miles from the railroad. Service failures increasingly affected not only train dispatching but the total information systems serving the entire company.

A basic policy problem affecting organization was "make or buy", that is, whether the railroad company should either provide its own communications services or purchase them, in whole or in part, from common-carrier communications companies. The most usual practice was to provide its own. There were then several organizational alternatives: the communications organization could be fully integrated into a line-staff engineering department; it could be partly or fully departmentalized within the engineering department; it could be ouside the engineering department but within the operating department; or it could be a separate department within the company.

Also, communications and signals could be integrated into one group, be separate groups reporting to the same official, or be organizationally separate from each other.

As a new concept, communications could be combined with computers into a separate information transmittal and processing department that would act as an information and data utility for the entire company.

Signals

Some differences of practice and opinion also applied to the organization of signal forces. It was generally agreed that they should be within the operating department, and usually that they belonged in the engineering department, though some signal officials questioned this. There were disagreements and differences in practice as to whether signal forces should be organized in a manner parallel to track and structures forces or should be more departmentalized. Signals were enough of a mystery to many engineering officials, and signal personnel were few enough in numbers, that signal forces usually functioned more intimately together than implied by any organization chart.

Engineering Design

There were many differences in regard to at what management level and in how many separate offices the designing of track, structures, architecture, signals, communications, and other facilities should be done.

In some companies all designing was done at headquarters. In another, structural and architectural designs were prepared at headquarters while those for signals and communications were produced in the district engineering offices. Another variation was for one or more categories of design, such as structural, architectural, and signal, to be prepared at both regional and headquarters levels. The regions did routine work while headquarters was taking on complex projects, acting as consultant to the regions, and handling overloads. Two companies each maintained a branch office of their headquarters engineering office in a distant city. In one, this was for structural design; in another for office engineering.

The trend was toward consolidation of design offices at fewer levels and locations. In some companies this was for all design; in others for one or more kinds only.

"Make or Buy" for Design

Practices differed, both between and within companies, as to whether the design of different kinds of facilities should be by company staff, by outside consulting engineers, or by both.

Four of the seven departments studied maintained competent structural design groups. Three planned to continue them. In the fourth there were conflicting opinions as to how much should continue to be done internally. The alternative was to use outside consulting engineers. This was the practice in two companies and was increasingly being done in a third. In the three first mentioned, outside assistance was sought only for complex special problems.

Some managements were reducing their structural design forces while still maintaining sizable signal design groups. One company had large structural and signal circuit design staffs but for years had routinely turned over to one consultant all design related to electric-traction fixed facilities. In another company with electrified operation, this design was done by company personnel.

Manufacturers, such as signal companies, sometimes designed not only their own equipment but also the related field installations. Railroad engineers sometimes developed design concepts for equipment as was done for CTC in one company and for a system for transmitting data in another.

Consultants would have had difficulty designing signal circuits, due to their unique railroad character, and because intimate familiarity with already existing plant out on line would be required.

Consulting engineers' roles differed. They might design some or all new work and some or all changes and repairs, with company staff doing the rest. The particular consultant already mentioned who was working on electric traction appeared to require little supervision and guidance; this firm had designed the original installation. When different consultants were designing different projects more effort by a railroad's engineers was required. No matter how much work was given out, some staff were still needed within a department for planning, establishing standards and criteria, scheduling, guidance, supervision, and review and approval of completed plans.

Advantages of consultants included the need for smaller company staffs, less problems with peaks and valleys of work load, reliance upon the consultant to keep abreast of new technical developments, and availability of specialized expertise when required. Disadvantages included possible higher cost, less responsiveness to urgent needs, more liaison problems, less familiarity with railroad requirements, reduced professional challenge to remaining railroad-employed design engineers, and reduced career advancement opportunities for them.

Design of Reimbursable Outside Work

A related policy issue was whether an engineering department should prepare designs for outside clients. Some railroad companies contracted with government agencies to design the highway–railway grade separations, bridges, and line changes which were often required for highway, water resource, and other public works projects affecting their properties. Other managements preferred to let the government agencies and their consultants do this work; the railroad's engineers limited their activity to establishing criteria, liaison, review, and approval of completed designs. At least one had in the past designed signal circuits for other railroads. In two companies where engineering departments did not do engineering designing for outside agencies, the technical research departments were actively performing contract research and development for outside clients. Some companies, though not interested in performing for-hire engineering services closely related to the railroad, were at the same time diversifying into industries totally unrelated to railway technology.

Among the claimed advantages of design groups performing outside work were the net financial contributions of overhead charges, the opportunity to maintain a larger and more varied staff, and the professional stimuli resulting from increased contacts outside the railroad. Those opposed were usually trying to reduce total engineering personnel. They also feared that a larger staff might have insufficient work to keep busy if a slackening of this type of demand would develop.

Minor Architectural Design

For almost every type of fixed plant there were officials at higher organizational levels to whom division maintenance personnel could turn for staff assistance. For the many problems associated with minor repairs to buildings, however, the division supervisors and foremen often had to prepare "back of an envelope" designs. This was because the architectural help they needed was not readily available. The architects at headquarters were organizationally and physically far away, and functionally concerned primarily with larger projects.

Construction Supervision

Each company organized construction supervision differently. Sometimes this was also true within a single company as between projects being built by outside contractors and by railroad forces.

In the four larger departments included in this study, construction was the primary concern of intermediate or headquarters level officials rather than of division forces, with the exception of small projects.

One of these companies maintained a large construction organization to supervise outside contractors. This was divided into four geographic areas all of which reported to a single assistant chief engineer. The operating regions only supervised the construction undertaken by company forces, such as track. In another company construction was under the two assistant chief engineers, each responsible for many activities on half the railroad. On yet another railroad supervision of large construction projects was by a smaller staff under an engineer of construction who reported to an assistant chief engineer. In a fourth, supervision of construction by outside contractors and company forces was the responsibility of regional officials.

Innovation

The organization, administration, operation, work atmosphere, and personnel management of the different individuals and groups concerned with innovation were all different, even within a single company.

In some companies, separate research and development departments and industrial engineering organizations were working on new ideas and improvements of methods.

In the engineering departments, usually at headquarters, individuals and groups were also assigned to developing and testing new ideas. They often had no extensive professional training or experience in research, development, or industrial engineering.

Within some companies, there was little interchange of personnel between engineering departments and research departments. There was often little opportunity for engineers working in lower organizational levels to participate. One large engineering department brought one engineer from out on line into its testing program each year, for a two-year tour of duty.

Long-range planning was seldom an explicit responsibility or activity. "Think" was a word not found in position descriptions.

However, two interdepartmental study groups that included engineering department representatives were observed working on new data-communications and signal concepts.

Arrangements for interchange of ideas with people in other railroads and in outside industry differed. Some personnel in research and development departments had frequent opportunities to exchange ideas with others, including participating in activities of many professional associations and even traveling to Europe and Japan. Engineering officials tried to "keep abreast" of developments, sometimes visiting other railroads and also relying on manufacturers, sales engineers, trade journals, and other sources.

Many engineers employed on different railroads worked together on new ideas as members of technical committees of the Association of American Railroads and the American Railway Engineering Association. There appeared to be relatively little interchange of ideas, and practically none of personnel, between individual companies on the one hand and the Research Center of the Association of American Railroads on the other.

Working relationships with the faculties and research groups of universities, except for occasional participation in short courses and the few professors on AREA committees, were rare.

GENERAL CONCLUSIONS

These conclusions apply specifically to the seven railroad companies that were studied in detail, and generally to many others as well.

The fixed facilities and the functions associated with them were all similar. They were, with few exceptions, the responsibility of the engineering departments. all of which were within the operating departments.

The engineering departments were decentralized organizationally into from one to four levels or echelons of management. There was always a headquarters, system, or general office. Usually below it there were separate units, in most cases called divisions, responsible for territorially separate portions of the railroad. Between these two there were in larger companies intermediate organizations called regions or districts, each of which included several of the divisions. All were linked organizationally to each other by various combinations of line and staff relationships, some of them quite complex.

In different companies, the engineering department responsibilities were distributed differently among the separate engineering offices and their officials. The internal organizations of these offices usually differed considerably at the headquarters and regional or district levels. However, they were quite similar in most divisions, though with several major exceptions. These differences included the staff sizes, the specific positions, their responsibilities, their relationships to each other, and so forth. Some organizational differences did not appear to be too significant in their effects upon the departments' work, while others were.

There were also many similarities among the engineering departments. There were positions at all organizational levels concerned with each of the major categories of fixed facilities, and positions associated with all major functions at either or both the headquarters and the intermediate levels.

In several of the companies, there were separate departments or groups engaged in technical research and development or industrial engineering related to the fixed plants. Innovation was also an active concern of many engineering officials. Practices as to interchanges of personnel and ideas between these groups were all different.

There was much less evidence of concern for long-range planning; major efforts of most officials seemed to be upon short term operations.

Many policies and practices were observed that had significant effects upon engineering-department organization structures, differences between the former were the reasons for the differences between the latter. Examples of such influences and their effects have already been given—only two are repeated here.

If engineers within a company did the structural designing then the organization of that function, including size and duties of the staff, was quite different than when this work was largely contracted to outside consulting engineers. If administrative "paper work" was prepared at all organizational levels the corollary requirements for liaison, coordination, and review, the number of staff, and the proportion of their efforts devoted to this in each of the offices were quite extensive. On the other hand, if various aspects of this work were centralized at one or another level, less of it was then of concern to other offices.

Organizational structures also influenced policies and practices. In each company the career development of engineering personnel was very much affected by the number and types of positions, their principal duties, and their geographical and organizational locations. Existence of an intermediate organizational level increased the problems of coordination and liaison between headquarters and divisions over those in departments with two-level management structures. Other examples have been given earlier.

There was a kaleidoscopic quality to most engineering department organizations. Just as that device presents changing patterns always composed from the same pieces of colored glass, so did these departments have frequently changing patterns of organizational arrangement of most of the same functions related to the same facilities.

OPINIONS AND SUGGESTIONS

During this study the author developed a number of opinions and suggestions, the most important of which are given here.

Organizational Structure

All the engineering departments fulfilled their assigned responsibilities. They did so using many different organizational structures.

Therefore, it appears that managements can change their engineering departments' organizations, either gradually or drastically (can any organizational changes be more drastic than those associated with major corporate mergers?), and the necessary work will be taken care of, provided there is adequate staffing and competent supervision for all the functions and facilities.

This does not mean that all patterns are equally desirable. The author suggests no measures for "best". He doubts that lowest short-term personnel cost, which appealed to several managements, should be included among them. On the other hand, corporate funds must be husbanded wisely, and some staffs had been too large.

Orderly organization charts and neat arrangements of line and staff responsibilities impressed the writer less and less as this study progressed. Other factors appeared more important. While a chart may look good on paper, people may not actually interact that way. It may be that new organizational patterns become effective only after new incumbents are installed in those positions that have been most significantly altered.

An organization suitable for one company may not be at all satisfactory for another. For example, it is hard to conceive of any two of the seven companies trading charts. This does not deny the value and importance of charts, for they help in planning how to organize people and activities together and in explaining what the relationships between them are supposed to be.

Organizational structure should suit the "atmosphere" of a company, the personalities of the senior officials, geographical requirements, and many other factors, while making optimum use of a reasonable number of personnel and providing "natural" lines of authority and communication.

It appears that organizations, no matter how carefully planned, are continuously modified. This was true in all the companies studied.

Line-Staff or Departmental Relationships

There are many arguments for and against both line-staff and departmental organizations. The principal argument in favor of the former is attractive—namely that it focuses overall responsibility more clearly at every organizational level. So is the one in favor of the latter—that it makes interactions between levels of organization easier.

Perhaps the relationships best suited to one type of function or facility are not desirable for another.

For the maintenance of track and structures, about which operating as well as engineering officials are so concerned, line-staff relationships may work well.

For technically complex specialties, often not fully understood by many of the higher officials who are responsible for them, particularly those requiring relatively small numbers of personnel, a formal departmental organization may be best. The people concerned usually operate this way anyway, informally. Workable formal provisions can then be devised for necessary liaison with other officials. Signals and communications are examples.

For activities like design, with their professionally specialized personnel, the "branch office" approach may be useful in geographically extended companies.

Multiple Levels of Management

The levels of management should be as few as possible, in the context of the usual line-staff organizations and the complications of liaison related to them.

If track mileage permits there should be a single division, for then liaison problems do not exist. If the lines are too extensive then two levels, with headquarters and some minimum number of divisions, will be required. In the geographically largest companies, including those being created by corporate mergers, three-level organizations may continue to be needed, as the span of control of headquarters over divisions would otherwise be too large.

Having regions direct the divisions below them, acting in many ways like headquarters of smaller subsidiaries, seemed appealing.

The author liked one organization with departmental relationships between divisions and regions and line-staff relationships between regions and headquarters; this seemed to provide the best features of both. However, this arrangement, devised by a management consultant, was progressively dismantled, starting shortly after it went into effect. It may have been a good idea in the wrong company. The relationships may have been too novel and intricate and the personalities and desires of higher officials may have been incompatible with these patterns.

The author favors a role for the intermediate levels, in large companies, of active direction. This reduces such efforts at headquarters, which are then left free to concentrate upon providing broad direction and specialized services. It also reduces the liaison that adds another management activity and often increases confusion too.

A final point: If headquarters is going to try to participate in everything that happens, it is suggested that this be made organizationally easy, or else impossible.

Author's Concept of Organization

These comments lead to the author's concept of an engineering department organized with a variety of concurrent relationships within a single overall organizational structure. Each major category of functions or facilities would be organized in a pattern especially designed to suit the specific needs associated with it. They would not all be forced into one standard format.

Career Development

Suggestions about career development of engineering department personnel are in an earlier paper.[2] The author feels as strongly as he did then that industrial engineering is a particularly appropriate educational background for railway maintenance. He feels even more strongly that railway companies are lagging far behind many other technically complex industries in developing programs for further formal education of their mid-career engineers. Very few engineers acquire graduate degrees during their years of active railroad service.

Long-Range Planning

Long-range planning should be given more attention, with an organizational unit formally responsible for it. In an industry with a changing function in the market place and with expensive long-lived plant subject to technical innovation and obsolescence, it would seem particularly appropriate to consider a railroad company's role well into the future and then integrate plant, operations, and organization into a staged program of adjustment related to it.

Innovation

Individuals, groups, and departments concerned with innovation within a single company should interact more closely, including more exchanges of personnel between them. There might also be tours of duty for engineers from individual railroads (and perhaps from railway supply companies also) at the Research Center of the Association of American Railroads, to aid the exchange of ideas, and to bring the groups closer together.

Office Engineering

Office engineering can be drastically reduced. The minimum amount that must be done should be determined. This should then be assigned to as few separate offices and levels of management as possible, thus automatically eliminating required liaison and review. Much of it should be handled by specialists, to increase productivity and to reduce costs.

Valuation

The valuation process could be made into a useful one. Engineering economy should be substituted for the AFE approach now used for analyses of proposed capital investments. The AFE should be reduced to its minimum role required by regulatory agencies.

Design

The author has no strong feelings about "make or buy" for engineering design. There seems to be a "critical mass" phenomenon as to how small a design group can be and still function well. If consultants are used, adequate staff must be provided for thier supervision. Whether added outside work might make it attractive to increase the staff of a design office to some more effective size should also be considered. Whichever course is followed, the author urges management to see that the work is done well.

Data—Communications

Communications and electronic data processing have nothing inherently in common with either railroad maintenance or accounting. A new "Department of information Transmittal and Processing" or "Department of Information Systems" would serve the entire company as an internal "utility". It would be totally divorced from all groups, like accounting, management systems, and operations, and the uses these groups make of these physical facilities.

Informal Communications

Efforts should be made to develop easier interpersonal communications and greater mutual trust. There should be less emphasis upon everything being on paper "for the record" and to use for fixing blame in case of trouble. Some railroad companies are at least as cumbersome as some governmental agencies about this. The example of one of the companies studied, described earlier, should be more widely followed.

Management by Exception

Management by exception should be more widely practiced. Lower officials should follow broad policy guidelines. These should be provided to them along with criteria for what should be brought to the attention of higher management. This would be difficult to arrange as many headquarters officials, including chief engineers, after long years climbing through all sorts of intermediate positions seem almost instinctively to try to be involved in everything.

Continuing Exchange of Management Ideas

All managements could find many new ideas for improving the organization and administration of their engineering departments by looking no further than within their own railway industry. In every company the author found features that appeared desirable for introduction into one or more of the others. Also, every organization had at least one "sacred cow" not necessary in any other.

There is now no effective forum for the continuing exchange of ideas on railroad organization and administration. The committees of the American Railway Engineering Association are primarily concerned with technical details. Several have assignments related in small part to economics, personnel development, valuation, forms, procedures, and the like, but there is no committee with the specific assignment of studying engineering department management. The Railway Systems and Management Association, on the other hand, includes all aspects of railway management, including some of concern to engineering departments, in its programs. However, it does not provide the opportunities for people to work continuously together, year after year, as AREA committees do so unusually well.

The author suggests again, as he did in his 1960 paper, the creation of a new AREA committee, which could be entitled the "Committee on Management of Railway Engineering". Membership should include chief engineers, senior engineering officials, organization planning specialists, interested university faculty, management consultants, and similar individuals. This new committee would function in the same manner as the existing ones do, with the members engaged in continuing studies and exchanges of ideas. These would be related to the objectives of the committee—gathering and developing ideas for further improvement of the management of railway engineering departments.

ACKNOWLEDGMENTS

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The generous help given by higher managements, operating and engineering officials, and their staffs; on 7 railroads, some 200 people in all; is gratefully acknowledged. The author has a lifelong debt of gratitude to his advisor, Dean George P. Baker, of the Harvard Business School. Many other people gave valuable suggestions.

All findings, opinions, and errors are, for better or for worse, entirely the responsibility of the author.

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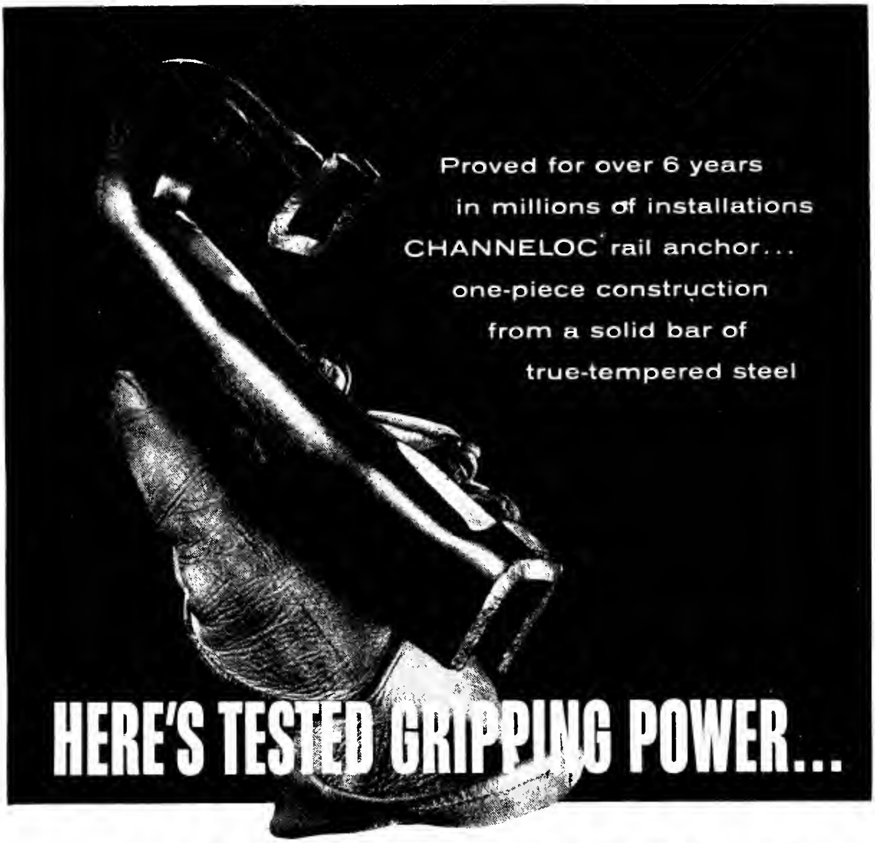

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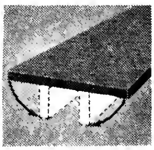

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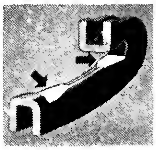

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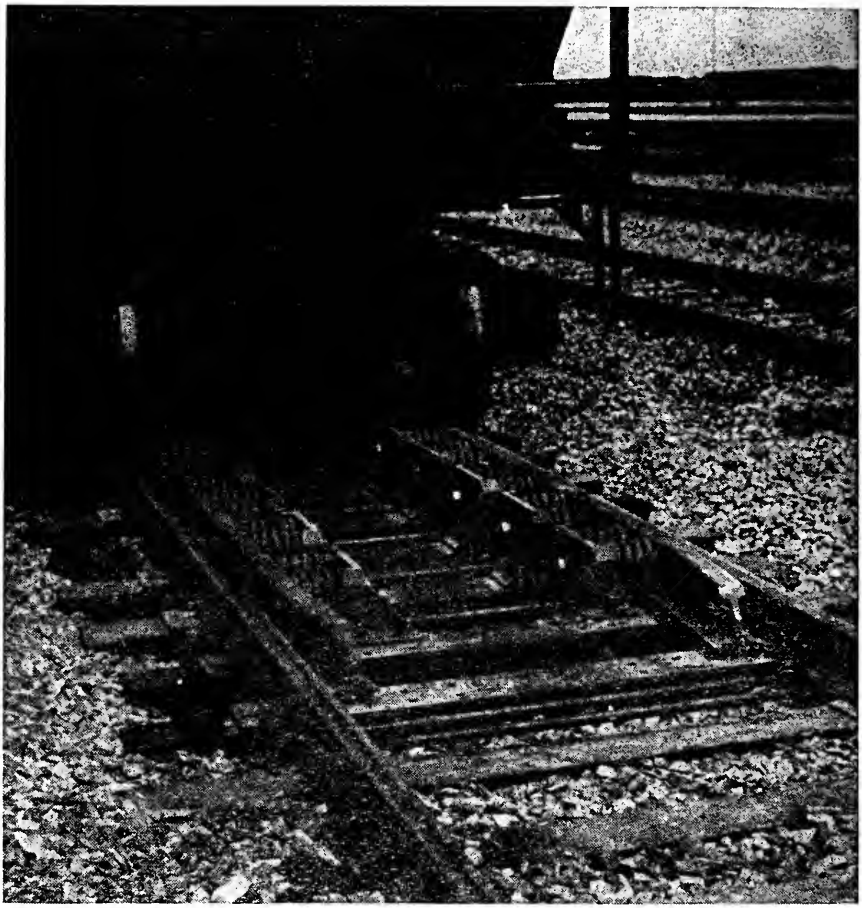

American Railway Engineering Association—Bulletin

Bulletin 609 November 1967
Proceedings Vol. 69*

REPORTS OF COMMITTEES

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The reports in this issue of the Bulletin will be presented to the 1968 Annual Convention of the Association at the Palmer House, Chicago, March 19–21, 1968. Comments and discussion with respect to any of the reports are solicited, and should be addressed to the chairman of the committee involved, in writing, in advance of the Meeting, or from the floor during the Meeting.

* The contents of this Bulletin and the other Bulletins of the Association from Bulletin 608, September–October 1967, to and including Bulletin 614, June–July 1968 (except Bulletin 613, March 1968), will constitute the Annual Proceedings of the Association, Vol. 69.

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Report of Committee 16—Economics of Railway Location and Operation

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Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 16.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report this year. We expect to submit the final drafts to the full committee at the January 1968 meeting covering: Part 1—Location, and Part 2—Train Performance, excepting pages 16–2–12, and 16–2–19 through 16–2–24. In addition, the subcommittee is investigating the effect "track oilers" have on train resistance.

2. Engineering methods and economic considerations involved in improving the quality of transportation service.

   Report entitled "The Potential for Improvement in Freight Car Utilization" was submitted as advance information, and appears in Bulletin 608, September–October 1967. Progress is underway on development of additional reports.

3. Determination of maintenance-of-way expense variation with various traffic volumes and effect of using such variations, in terms of equated mileage or other derived factors, for allocation of available funds to maintenance-of-way, collaborating with Committees 11 and 22.

   The subcommittee found important deficiences in the analytic approach, the data and the conclusions of the research report prepared for this assignment. The report was not acceptable to Committee 16. Meetings of the subcommittee, AAR Engineering Research personnel and IITRI led to (1) re-inspecting the 42 one-mile test sections and checking the 40 characteristics of each, (2) correcting some data in the 44 expenditure codes for the 34-month test period analyzed earlier, (3) continuing data collection which now extends 44 months through July 1967 and (4) suggesting techniques and hypotheses for improved analysis. The 44-month data was retabulated in August and will be reanalyzed in November 1967. Committee 16 requested $12,000 appropriation for 1967–1968 to supplement the $33,000 appropriated 1961–1967.

4. Potential application of electronic computers to railway engineering and maintenance problems in research, design, inventory, etc., collaborating with Committees 11 and 30, and informally with the Railway Systems and Management Association.

   Report entitled "Use of Computer to Analyze Train Delay Problems" was submitted as advance information and appears in Bulletin 608, September–October 1967.

5. Location and operation of metropolitan systems as related to current railway operations.

   No report at this time. A paper is being prepared by a member of the subcommittee who has been on assignment in England studying rapid transit for Manchester, England.

6. Features of economic and engineering interest in the study, design, construction and operation of new railway line projects, or major line relocations, proposed, in progress or recently completed.

   Final reports entitled "Proposed Zambia-East Africa Rail Line—British–Canadian Survey 1966" and "Construction of a Spur Track Built on a 5.6 Percent Grade to Serve the Boeing Company Near Everett, Wash." were submitted as advance information and appear in Bulletin 608, September–October 1967.

7. Application of industrial engineering functions to the railroad industry.

   Report entitled "Determine Optimum Location for Hot Box Detector" submitted as information .... page 127

8. Investigate the use and value of network analysis and make appropriate recommendations for its application to railway functions, collaborating, as necessary or desirable, with the Special Committee on Systems Engineering.

   Introductory report, submitted as information .... page 137

9. Determine the additional costs for construction, operation and maintenance that are incurred in upgrading present main track to support very high-sustained speeds above 80 mph, in increments of 10 mph.

No report at this time. This is a new subject this year. Progress report will be submitted later.

THE COMMITTEE ON ECONOMICS OF RAILWAY LOCATION AND OPERATION,

L. E. Ward, *Chairman.*

AREA Bulletin 609, November 1967

Report on Assignment 7

Applications of Industrial Engineering Functions to the Railroad Industry

K. A. KOOMANOFF (chairman, subcommittee), K. W. BRADLEY (vice chairman, subcommittee), C. P. CHITWOOD, W. J. DIXON, G. W. GUTHRIE, H. J. KAY, RAYMOND MCCANN, R. W. MCKNIGHT, R. L. MILNER, J. F. PARTRIDGE, J. J. STARK, JR., C. L. TOWLE, ROLAND TURNER, D. M. WEINROTH, P. B. WILSON, D. R. WHEELER.

Determine Optimum Location for Hotbox Detectors

This report is concerned with the present practices of 43 railroads in locating hotbox detectors. Also included is a listing of the factors that these roads feel are important in determining detector location. Such items as geography, number of trains, kind of traffic, location of set-off points, and others are discussed. Information is also included concerning the means taken to alert train crews, once an overheated journal has been detected. Inspection practices are discussed briefly, as they relate to hotbox detection.

Appendix A contains a selected bibliography of articles appearing in the trade press about hotbox detectors.

Subsequent reports on this subject will cover scientific methods used by some railroads in determining hotbox detector locations. Items to be reported will include derailment location analysis; methods of economic justification; relationships between hotboxes per mile, tons per mile; derailments per hotbox and number of derailments.

Present indications are that some form of probability statistics may provide a practical solution to the problem of determining hotbox detector location. A few railroads are now working in this direction. They hope to be able to predict the probability of a hotbox developing, and analyze the effectiveness of their detectors. Not only do they anticipate the possibility of improving location determinations, but they expect to be able to obtain rates of return on investment for their hotbox detector installations.

This aspect of statistical analysis will be pursued by your committee after work has been completed on the next task, namely, that of obtaining information on scientific methods used to determine detector location as utilized by several railroads.

DETECTOR SPACING: PRACTICES ON 43 RAILROADS

Information was obtained from 43 railroads having 1100 hotbox detectors in service. Eighteen railroads having 930 line-of-road hotbox detectors provided data as regards spacing of these detectors. Using the weighted average concept, it is determined that these roads are spacing line-of-road hotbox detectors at about 35-mile intervals. Twenty-seven railroads have 997 hotbox detectors located to inspect trains entering or leaving yards. The weighted average indicates that a hotbox detector is located 20 miles from a yard.

It should be pointed out that information was not always available to determine distances for all detectors listed by a railroad. Some railroads are concentrating their installations for yard entrance and exit scanning. Where this is done, many spot a line-of-road detector midway between major yards. However, for those roads with the largest number of hotbox detectors, data were available for determining a large sample of typical distances for line-of-road and yard entrance detectors.

Although averages cover up some trends and specific situations, analysis revealed that most roads are increasing the distances of yard entrance detection locations. When these detectors were first installed, many roads located yard entrance scanners about 5 miles from a yard. More recent installations are being made with this distance increasing to 20 miles. However, it should be noted that it may not be more economical to increase the distance from yard entrances. Usually there are converging routes close to yards and one hotbox detector near the yard entrances would cover all these routes. The economics clearly depend on the number of diverging routes and the distance from the yard entrance. Only an analysis of derailment locations can determine if this lengthening of yard entrance scanning distance is satisfactory. Analysis of set-offs might also indicate if this stretching of yard entrance scanning distances is worthwhile.

NEED FOR HOTBOX DETECTORS

A look at some figures provided by the Interstate Commerce Commission and others provided by the Mechanical Division of the Association of American Railroads reveals much concerning the hotbox problem. ICC figures reveal that during 1965 there were 454 derailments due to overheated journals. This figure had been steadily rising from a low of 346 in 1962. During 1965, the AAR Mechanical Division reported that 23,798 cars were set off between terminals because of overheated journals. These cars were equipped with plain bearings and lubricator pads. Also, during 1965, a total of 469 roller-bearing-equipped cars were set off between terminals for the same overheated condition.

The above is costing the railroads money. For example, using ICC figures for cost of derailments of $25,000—this covers only damage to track and equipment—the 1965 derailments cost the railroads $11,350,000. However, using a more realistic figure of $200,000 these 454 derailments due to overheated journals represent an expenditure of $90.8 million. The real financial outlay for a derailment, in addition to damage to track, freight cars and locomotives, will include:

- Labor and materials required by the wreck crew in cleaning up after a derailment.
- Costs to cover repair or replacement of damaged signal and communications lines.
- Labor and materials for restoring the line to normal service.

- Costs of detouring trains, if necessary, until normal operation is restored.
- Loss and damage to freight, and costs not covered by insurance.
- Intangible costs including loss of future business by shippers who feel a railroad has "too many" derailments. Delays to shipments directly or indirectly involved in the derailment also incur shipper dissatisfaction.

One railroad estimates that it costs $300 when a car is set off for a hotbox, and must be repaired. This figure does not include any special moves that might be made for the delayed car to be immediately moved when possible. Thus, the 24,267 set offs cost the railroads $7,280,100 for repairing the journals.

Cost of car set-offs, say some, is really irrelevant or even possibly misleading, for economic justification of hotbox detector usage. Even with a hotbox detector system, cars will be set off. If the threshold of the detector is set low, so as not to miss any overheated journals, then set-offs will increase because of detector actuations. If, on the other hand, the threshold is set high to reduce set-offs, then an overheated journal may pass the detector and not be alarmed as an abnormal condition.

RULE OF THUMB FOR LOCATIONS

A rule of thumb has been used by many railroads for the location of hotbox detectors, namely, to locate detectors 25 to 30 miles apart along line-of-road, and in approaches to yards they should be about 5 to 10 miles out. For trains leaving yards, the 30-mile distance is considered proper. The reasoning, borne out by experience of many roads, is that if a journal is going to overheat it will do so in about 30 miles.

The yard entrance spacing of 5 to 10 miles was developed in the early days of hotbox detectors (first one was installed in 1956) because they could only scan in one direction. Thus, the detector "watching" outbound trains could not scan inbound trains. However, with the development of controls for bi-directional scanning, the outbound detector can scan inbound trains. At first it was thought desirable to scan trains as close to yards as possible, thus providing the car inspection forces accurate, up-to-date information. Many railroads are finding a compromise by providing a satisfactory answer to yard entrance and exit detection sites. They place detectors about 15 to 20 miles from yards and scan trains entering and leaving these yards.

There are two general schools of thought with respect to locating hotbox detectors: (1) place detectors where the largest number of hotboxes occur; (2) cover all lines with major traffic densities and all major yard entrances. Actually, many roads started out with the first principle. However, as they found that they were just putting out fires in specific areas, and possibly not catching the majority of hotboxes, they soon became convinced that an overall program of hotbox detection would be necessary. A few railroads, once they decided that they must install hotbox detectors, embarked on a systematic program of installing them along all main lines and bracketing major yards.

A few railroads, when planning to install hotbox detectors, make an economic analysis of the traffic handled in the territory under consideration. Factors to be taken into account include number of trains, type of traffic handled, value of this traffic, including revenue derived from it, past history of derailments in the territory and the causes, geography of the line including availability of set-off locations, etc. It may be a case of balancing costs of detection equipment against the probability of derailments and/or set-offs, and how much these set-offs or derailments would cost the railroad. This economic analysis approach will probably gain favor because of the availability of computer-oriented research procedures for readily making such studies.

Some roads, when they are not yet convinced of the system-wide approach, or are just trying to protect the most likely locations for overheated journals, often will spot a line-of-road detector midway between major yards which are bracketed with hotbox detectors. In this manner, they get yard coverage and a semblance of line-of-road coverage. At least they get spot checks along the line, although admittedly not the solid coverage they would get with the 25- to 30-mile spacings for line-of-road detection practices.

WHAT IS A HOTBOX DETECTOR?

To begin talking about specific locations for a hotbox detector, it might be worthwhile to define our terms. A hotbox detector is a device for scanning passing journals or the top part of the truck side-frames of moving cars and locomotives. It consists of wayside scanners, readout equipment made up of graphic recorders using paper and ink or heat stylii, and associated computer and alarm units. Also, digital and voice recording equipment may be used to provide readout or notify crews of overheated journals. What we shall now discuss is the location of the wayside scanners or heat-sensing equipment. (Note: Hotbox detector manufacturers are listed in the bibliography for the reader who desires more detailed information concerning these devices.) It should be noted that two hotbox detectors scan the underside of the passing journal boxes. One detector scans the hub of the wheel. The fourth detector manufactured scans the top of the truck side-frame.

Detectors should be located where: (1) there is tangent track, (2) there has not just been a brake application, (3) they are accessible for maintenance, (4) a tie to existing communications is feasible, (5) there is a power supply, (6) the roadbed is stable, (7) sunlight will not be a problem, (8) the trains can be stopped without interference, (9) there are existing tracks that can be used for set-offs, and (10) the set-offs are accessible for car repair.

Generally speaking, most railroads agree that the hotbox detector scanners should be located on tangent track. One road has a requirement that there should be a minimum of 1000' ft of tangent track in approach to the scanner. Also, scanners should not be located in areas where trains are braking. While braking itself is not necessarily a cause of hotboxes, heat generated from braking may cause a hotbox scanner to give a false indication. A problem is that if a higher threshold is set for the scanner, it may "miss" abnormal journals.

Additionally, the scanner site should be accessible so maintenance personnel can reach it. Communications facilities such as signal and/or communications pole line should be available. There should be a source of power: 115 v, ac, 60 Hertz (cycles per second), single phase.

A STABLE ROADBED IS REQUIRED

A necessary requirement is that a stable roadbed be provided. Generally, the scanners are mounted on separate steel or concrete foundations so that train vibration will not be transmitted to the electronic equipment in the scanner. However, the relative positioning of the scanner with respect to the track must be maintained. Although springing of trucks is taken into consideration, it must be remembered that the scanner is aimed at a specific area of the journal box, side-frame or wheel hub. Alignment of the scanner is one of the many routine maintenance tasks performed. For some roads, where tracks run in an east-west direction, there may be a problem of sunlight at early morning or late afternoon falling upon the scanner. Normally, the scanner shutter is open only for the brief instant of time when the journal box is in the correct viewing position. Some roads that have experienced the sunshine problem have installed pipe extensions on the front of the scanner. In all cases, however, care must be taken to keep the scanner outside clearance limits.

Most roads have installed wood or heavy steel plates on each side of the scanner to prevent dragging equipment from damaging it. One manufacturer recommends that guard rails be installed in approach to scanners to align skewed trucks.

Relative to scanner location is the point at which the train will stop if an overheated journal is detected. Most roads work on the assumption that the entire train will pass the scanner, and assuming the crew is immediately alerted, that the engineman will apply a normal brake application to bring the train to a stop. For example, the train should not stop so that it is blocking a yard entrance, sitting on the approach circuits, or actually in an interlocking. Also, the train should not be stopped so that it is on a restricting grade or blocking important highway-railroad grade crossings. Additionally, the train should be stopped short of the tunnel, bridge, or other structure that is protected by the detector.

One of the reasons for placing hotbox detectors close to yard entrances, say about 5 miles, was that the train would pull into the yard without stopping once it passed the detector. This practice is still followed by many roads, except in emergencies where the recorder tape might indicate an extremely hot journal. In such an instance, if the train crew can be alerted, they would probably stop the train before entering the yard.

Another requirement for hotbox detector location is that a set-off be near where the train is to stop if it has an overheated journal. This set-off location should be accessible so that car department personnel can, if desirable, drive to the site in a truck to make repairs.

At this train-stopping location, there must be communications available for the train crew. They should be able to telephone to the dispatcher. He may inform them of the specific journal in trouble. Or, they may read a digital readout device in a wayside instrument house. In either case, they will have to contact the dispatcher to tell him what action they have taken.

Thus, it is apparent that some braking distance calculations must be made for each hotbox detector location. Accordingly, it is important to know the speed limits in the territory as well as the type of traffic, including tonnage of trains.

ALERTING TRAIN CREWS

To alert train crews of overheated journals, various methods are used. If the detector is in automatic block signal territory, the detector may be interconnected with the signal system. If this is done, then the detection of an overheated journal will cause a signal ahead of the train to display the Approach aspect, and the second signal ahead of the train will display a Stop aspect. In this manner, the train crew will operate under signal rules, and accordingly will stop the train. Again, at the train-stopping location, there will be a telephone for communication with the dispatcher or the person who has observed a recording or other readout device indicating the hot journals. Some roads which make use of the signal system provide a digital readout device at the signal displaying the Stop aspect. This is so the train crew can determine which journal is in trouble and then make an inspection.

The trend is away from the practice of interconnection of hotbox detection devices with the automatic block signal system. The main reason is the requirement of providing an Approach aspect to an engineman before he receives a Stop aspect. As a result, a train (when operating where such inter-connection is in service) might travel several miles before being stopped by a Red signal. There are other means by which the train crew can be alerted, and more immediately.

Radio is used by many railroads for alerting train crews of an overheated journal. In some cases, the hotbox detector information is telemetered to an interlocking tower, yard office, block station or dispatcher's office. The operator, car foreman, or dispatcher may use a local base radio station to contact the train crew. In the case of a dispatcher, where the train is many miles away, he may remotely control a wayside base radio station for contacting the train crew.

One railroad telemeters information from all its line-of-road hotbox detectors to a central office, where supervisory personnel read the recording charts. Visible and audible alarms (light and bell) sound when an overheated journal is detected. The supervisor checks the appropriate tape, and via remote control of base radio stations can talk directly to the crew of the train concerned.

On this and other roads using radio, the trains are also equipped with two-way radio, both end-to-end and for train-to-wayside communication. General practice, in this type of communication, is for the train crew to radio directly to the person informing them of the overheated journals.

Another railroad makes use of wayside radio stations at the scanner sites and lets voice recordings broadcast the detector information to the crews of passing trains. Using a bank of pre-recorded messages, the appropriate message is radioed to the crew of the passing train. If there is no overheated journal on the train, the recording broadcast to the train so states.

INFORMATION SIGNALS

Several railroads make use of hotbox indicators information signals to alert train crews of overheated journals. In most installations, actuation of the detector causes a lunar white light to flash. This indicator lamp is mounted at the scanner site, usually on a signal mast. Or it may be mounted on the mast of the first automatic signal the train passes after leaving the scanner site. This alerts the crew that a hotbox has been detected. Braking distance away from this flashing lunar white indicator will be a second indicator lamp. It will display white letters on a black background. It may spell "HOTBOX", or simply the single letter "H". This indicator will be located at the site of readout equipment. Usually, it is simply a numerical display of the number of journals from the caboose indicating overheated ones. There will be a reading for both sides of the train. Most digital or numerical readouts will display up to four hotboxes on each side of a train. Telephone or radio communications are available for contacting the dispatcher.

One railroad employs a tote board or numerical display board of sufficient size for the train crew to read it as they approach. This display board is usually located about 10,000 ft beyond the hotbox scanners. If an overheated journal is detected, the journal number (counting from the caboose forward) is displayed. Numbers can be displayed for either side of the train. When the board is lighted, a flashing light atop the board (white) alerts the crew that a hotbox has been detected. If no hotbox is found by the detector, the display board is dark and the flashing light is also dark.

Several railroads make use of interlocking home signals, and other controlled signals, such as siding entrance and leaving signals in centralized traffic control territory, for stopping trains which have indicated hotboxes. When the dispatcher or interlocking operator is alerted that a hotbox has been detected on a train, he simply sets a signal to the Stop position. When a member of the crew telephones or radios the dispatcher or operator, he tells them which journal to inspect.

INSPECTION PRACTICES

For yard entrance detection, most railroads allow trains to proceed into the yard, where it is then inspected. For yard inspection detectors, the readout is usually in the form of recording chart paper, with the recorder located in the yard office, car foreman's office or some location where car inspectors are available.

Several railroads follow the practice of having car inspectors check only those journals that are indicated hot or in an approaching "hot" condition. One road checks all cars arriving in interchange at the first inspection point. Thereafter, car inspections are based upon hotbox detector reports.

A practice among many railroads is to alert yard inspection forces about journals that may be heating up, but have not reached the critical stage when the train is yarded.

For line-of-road inspections by train crews, many railroads advise crews to check journals on three cars—the car indicated having an overheated journal, and the car ahead of and behind the troubled car.

Higher train speeds plus greater acceleration due to higher horsepower locomotives lead some to believe that these two factors can cause a journal to heat up to the danger point in less than 30 miles. On one railroad a considerable number of hotbox incidents occurred between detectors spaced 30 miles apart. That is, a journal went by a detector as normal, but overheated before it reached a second detector only 30 miles distant. One solution appears to be closer spacing of line-of-road detectors. However, could the same problem be solved by more and careful attention to inspection practices? In the hurry to get trains out of yards, are they being given the proper inspections, or is it just a quick check of the worst journals?

Some roads have reported that even with lubricator pads, cases have been found where the pad was wedged improperly in the box, causing improper lubrication. In some instances, pads have been broken or torn by the use of "jimmies" or packing irons to poke them in place. Often this tearing will prevent them from wicking properly, so that there is uneven distribution of the lubricating oil. With roller bearings, there is not quite such an inspection problem, because they are inspected every 12 or 18 months, depending upon the type.

As might be expected, many railroads have more hotboxes in spring and summer than in fall and winter. Higher ambient temperatures occur during the spring and summer months. But, we do have some railroads operating through warm climates in the U.S. While not enough information has been developed to really answer this puzzle, some of the roads in the southern parts of the U.S. find no real difference between the seasons. Where roads operate in areas with cold winters, and in areas where there is a wide variation in ambient temperature, a partial solution has been the use of heaters and other devices to provide constant ambient temperatures for the scanners.

Most railroads report that seasonal variations require different settings of gain on the amplifier equipment to provide a pen-graph deflection that is proper for the season. Some detectors operate on a differential between scans on both ends of the same axle. There may be a problem if both journals on the same axle are hot. One road, working with a manufacturer, has come up with an electronic scheme for producing a tall pip on both recording tracks if both journals are overheated. In this case, the differential would be small, but the absolute value for either journal would be high.

Some railroads are finding that the locations picked for their first detector installations are no longer proper. One road has moved several detectors because a study has revealed that they are missing hot ones. In some territories, it is a case of running freight trains at higher speeds than when the detectors were installed several years ago.

STATISTICAL ANALYSIS

A possible solution to many of these problems is a statistical or mathematical approach. With the aid of the digital computer, considerable data concerning hotboxes, such as where they occur, where the car is set off, kind of car, weight, loaded or empty, type of journal, date of last inspection, type of inspection, how far traveled since last inspection, etc., might be developed into meaningful information.

One approach for catching journals on-line before they overheat or burn off is to make use of on-line computing. Whether the economics of the situation would justify tying in hotbox detector data to an on-line, real-time computer is not really known now. However, it has intriguing possibilities. All hotbox detector information would be telemetered into a computer, which would instantly analyze it. Comparison would be made on each journal with the detector report of a previous scan. Hotboxes could be flagged immediately, and journals just beginning to heat up could be flagged for attention at the proper time.

One might call it the ultimate, but with automatic car identification in service, car initial and number could be added to information on the specific journal in trouble. This could become possible without computer detection and analysis, as mentioned above.

One final word about efficiency: When applied to a hotbox detector, it really is a misnomer. Hotbox detector efficiency usually means the ratio of hotboxes found to the number indicated hot by the detector. This is misleading because people interpret a high numerical value for this ratio to mean that the device is efficient. If this ratio is low, the hotbox detector is considered inefficient.

What throws efficiency out of kilter is the ratio numerator—hotboxes found. The cause is the time lag that naturally occurs between the time the detector spots a hotbox until the train is stopped and the overheated journal found by a trainman or a car inspector. This time delay is sufficient in many cases to allow for proper cooling of a journal so that no hotbox is found. Hence, the efficiency ratio numerator falls, but this should not condemn the detector. It did its job properly, but the fact that a man cannot lift a journal box lid on a moving train necessitates the time delay. The threshold of the detector is quite critical. For example, by setting a high threshold we may get a very high ratio of hotboxes detected to actual hotboxes but in the process many potential hotboxes could be missed. Clearly, the ratio in this case is misleading.

Because the ratio is human detection (hotboxes found) vs. mechanical or electronic detection (hotboxes found by the detector), a suggestion has been made that, instead of efficiency, the term detection ratio be used.

CONCLUSION

There seems to be very little proven theory of hotbox detector location. The facts are hidden by averages, generalizations, and perhaps a little of the practical reaction decision that places a detector where the last major derailment occurred.

What we hope to accomplish in our present effort is to predict the probability of a hotbox developing on each segment of our system, analyze the effectiveness of our present detectors in the various territories, predict performance of additional detectors, and then draw up several plans that yield different rates of return on investment.

APPENDIX A—SELECTED BIBLIOGRAPHY CONCERNING HOTBOX DETECTION FROM 1956 TO 1966, INCL.

Note: RA = Railway Age
RS&C = Railway Signaling & Communications
MR = Modern Railroads

Atlantic Coast Line: MR Feb. 1965 p. 75

Automatic Detectors: RS&C June 1961 p. 19

Baltimore & Ohio: RS&C Sept. 1959 p. 45; RS&C Aug 1966 p. 13

Boston & Maine: MR Mar. 1958 p. 81; RS&C Nov. 1957 p. 35; RS&C Sept. 1959 p. 45; RS&C Nov. 1959 p. 43; RS&C July 1960 p. 34

Chesapeake & Ohio: MR May 1957 p. 141; RA Mar. 25, 1957 p. 19; RA July 22, 1957 p. 31; RS&C Apr. 1957 p. 56; RS&C July 1957 p. 46; RS&C Oct. 1958 p. 56; RS&C July 1960 p. 46; Sept. 1960 p. 28

Chicago, Rock Island & Pacific: RS&C Jan. 1957 p. 48

Clinchfield: RA Apr. 18, 1960 p. 23; RS&C Nov. 1959 p. 38; RS&C Apr. 1960 p. 15

Communication & Signal Section, AAR: RA Nov. 12, 1962 p. 33; RS&C Nov. 1961 p. 21; RS&C Nov. 1962 p. 22

Crews: RA Sept. 12, 1960, p. 14

Delaware & Hudson: RS&C May 1959 p. 63

Derailments: RS&C Aug. 1962 p. 32; RS&C Sept. 1962 p. 22

Efficiency: RA Oct. 31, 1960 p. 60; RS&C Oct. 1961 p. 5

Erie–Lackawanna: RA Nov. 14, 1960 p. 18; RS&C Sept. 1966 p. 52; RS&C Dec. 1960 p. 24

General Information: RA Nov. 25, 1957 p. 21; RA Sept. 22, 1958 p. 25

General Electric Co.: MR Nov. 1959 p. 87; RA Oct. 5, 1959 p. 14; RS&C Oct. 1959 p. 26; RS&C May 1962 p. 12; RS&C Aug. 1966 p. 19

General Railway Signal Co.: MR June 1960 p. 131; RA May 2, 1960 p. 15; RS&C May 1960 p. 29

Harmon Electronics Inc.: RS&C Oct. 1966 p. 37

In service: RA Feb. 19, 1962 p. 26

Interstate Commerce Commission: RS&C Mar. 1966 p. 27

Louisville & Nashville: RA Jan. 23, 1961 p. 36; RS&C Aug. 1959 p. 24; RS&C Sept. 1959 p. 45; RS&C July 1960 p. 34; RS&C Feb. 1961 p. 30; RS&C Aug. 1961 p. 44; RS&C Dec. 1961 p. 36

Maintenance: RS&C Sept. 1960 p. 28; RS&C July 1960 p. 34; RS&C Nov. 1960 p. 26

Milwaukee Road: RA Mar. 9, 1959 p. 52; RA Apr. 27, 1964 p. 17; RS&C Apr. 1959, p. 44; RS&C July 1960 p. 34; RS&C June 1964 p. 25

Missouri Pacific: RS&C July 1960 p. 44

New York Central: RA Mar. 31, 1958 p. 22; RS&C Mar. 1958 p. 40; RS&C Oct. 1958 p. 57

Norfolk & Western: RA July 1, 1957 p. 32; RA Oct. 26, 1959 p. 64; RA Oct. 15, 1962 p. 38; RA Sept. 12, 1966 p. 46; RS&C Dec. 1959 p. 24; RS&C July 1966 p. 22

Operation: RS&C Feb. 1964 p. 16

Pennsylvania: RA Feb. 9, 1959 p. 7; RA Mar. 16, 1959 p. 24; RS&C Mar. 1959 p. 48; RS&C Apr. 1959 p. 22; RS&C Sept. 1959 p. 25; RS&C Nov. 1959 p. 36; RS&C July 1960 p. 34

Pittsburgh & Lake Erie: RS&C Nov. 1959 p. 36; RS&C Dec. 1959 p. 20; RS&C Aug. 1960 p. 46

Progress Report: RA July 5, 1965 p. 21; RA Jan. 17, 1966 p. 58; RS&C Sept. 1958 p. 36; RS&C Feb. 1959 p. 30; RS&C Oct. 1959 p. 18; RS&C Oct. 1960 p. 19; RS&C Oct. 1961 p. 28; RS&C Apr. 1958 p. 56

Questions and Answers: RA Sept. 12, 1960 p. 50

Railtron Corp.: RS&C Apr. 1966 p. 30

Reading: MR Sept. 1966 p. 147; RA Mar. 4, 1957 p. 15; RA Apr. 1957 p. 47; RS&C Apr. 1957 p. 19; RS&C Nov. 1959 p. 36; RS&C Oct. 1966 p. 30; RA Sept. 26, 1966 p. 49

Research: RS&C Nov. 1965 p. 20; RS&C Aug. 1966 p. 26

Round-up: RA Sept. 30, 1957 p. 32

St. Louis–San Francisco: RS&C Mar. 1961 p. 27; RS&C July 1966 p. 23

Santa Fe: RS&C Mar. 1960 p. 38

Seaboard Air Line: MR June 1962 p. 61; RA Mar. 27, 1961 p. 68; RA July 24, 1961 p. 28; RA Feb. 26, 1962 p. 58; RA Oct. 29, 1962 p. 55; RS&C Apr. 1961 p. 45; RS&C July 1961 p. 22; RS&C Nov. 1962 p. 26

Servo Corp. of America: RA Sept. 8, 1958 p. 59; RA Aug. 3, 1959 p. 19; RS&C Apr. 1957 p. 19

Signal Officers: RA Nov. 30, 1959 p. 88

Signal Section, AAR: RA Oct. 19, 1959 p. 30; RS&C Oct. 1957 p. 60; RS&C Nov. 1959 p. 13; RS&C Nov. 1960 p. 26

Soo Line: MR March 1963 p. 103; RA Sept. 23, 1963 p. 52

Southeastern Railroads: RA Sept. 7, 1959 p. 44

Southern: MR June 1961 p. 137; RA Sept. 12, 1966 p. 46; RS&C Aug. 1961 p. 24; RS&C June 1962 p. 26; RS&C July 1966 p. 24; RS&C Aug. 1966 p. 26

Tell Crews: RA July 24, 1961 p. 25

Texas & Pacific: RA Nov. 21, 1960 p. 29; RS&C Dec. 1960 p. 44; RS&C Mar. 1961 p. 27

Union Switch & Signal Division of WABCO: RA Nov. 16, 1959 p. 16; RA May 23, 1960 p. 25; RS&C June 1960 p. 30

Western Maryland: RA Sept. 19, 1966 p. 38; RS&C Nov. 1966 p. 18

Report on Assignment 8

Investigate the Use and Value of Network Analysis and Make Appropriate Recommendations for Its Application to Railway Functions

Collaborating as Necessary or Desirable with the Special Committee on Systems Engineering

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Your committee submits as information the following report which will serve as an introduction to the subject. Specific applications will be covered subsequently in detailed reports.

In recent years, there has been a rapid growth in the application of network analysis and closely related techniques to the solution of a number of types of complex practical problems. Many of the problems that can be effectively attacked by network analysis are related to railroad construction and operation. A simplified example follows:

A yard and tracks serving various industries are arranged as shown in Fig. 1. Can a switch engine leave the yard, switch industries located throughout the lengths of tracks 1 through 7 and return to the yard without having to make an extra trip over any of the tracks? If the engine can, what route must it follow to avoid making an unnecessary trip over one of the tracks?

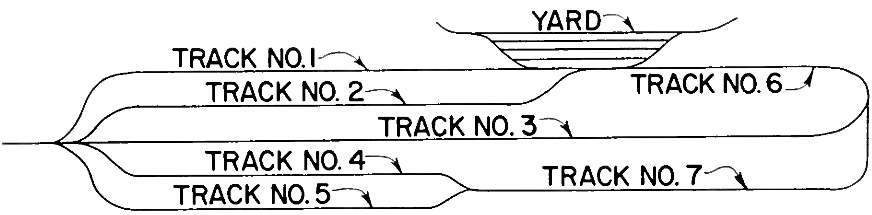

FIG. 1 INDUSTRY TRACK LAYOUT

In most cases, it is desired to determine quantitative values for certain characteristics of the network being investigated. If the problem is complex, computations may become excessive and the use of a computer to perform the required calculations may be advantageous or necessary. Before obtaining numerical results, however, it is necessary to correctly identify and define the qualitative aspects of the problem. Network analysis is a particularly valuable tool for qualitative study of a large class of problems since it allows representation of a system of relationships by a relatively simple visual model. Study can be concentrated on a limited portion of the network without isolating it from the rest of the system or the entire system can be studied as a whole.

Although many practical applications of network theory are of relatively recent origin, principles governing the relationships within networks or linear graphs were first formulated by Euler in the 18th Century. Until the middle of the 19th Century, however, the subject of network analysis was of little interest to anyone except mathematicians and was used primarily in the solution of geometric or logical problems such as the "Konigsberg Bridge Problem"* which was the subject of a paper written by Euler in 1736.

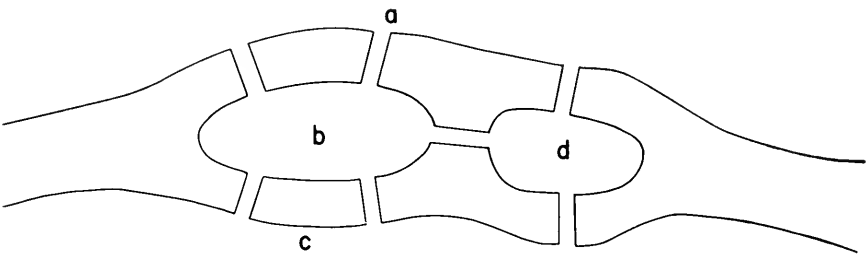

FIG. 2 THE SEVEN BRIDGES OF KÖNIGSBERG

Although the most obvious applications involve movements over or flows through physical networks, network analysis can be used to advantage in solving many problems that do not involve physical networks. In fact, any system of physical or logical relationships between objects, events, processes or ideas can be represented by a network. Electrical and water distribution systems (3),** railroad systems (1, 7, 8), structural frames (4, 10), economic and distribution problems (5), construction operations (2, 9, 12, 13), transitions in biological and physical systems, classification problems, organizational problems, molecules, and even interpersonal relationships (6) have been studied by network techniques.

A network consists of several individual elements interconnected in some particular way and the behavior of the individual elements is interrelated in a characteristic manner. A network may be visualized by means of a line drawing (linear graph) which depicts the relationships between the network elements. A linear graph (5, 6, 11) consists of nodes, represented by single points, and branches (arcs), represented by straight or curved line segments as shown in Fig. 3. The basic relationships between elements are independent of all bending, stretching or twisting distortions of the graph which do not sever any of the branches, i.e., they are topological properties of the graph. Note that the graph in Fig. 3 represents the problems shown in Figs. 1 and 2 and that these problems have identical solutions. The branches of a graph may be directed (have a head and a tail as in Fig. 4) or not depending on whether or not the relationships represented by the graph have directional properties. In a directed graph, two branches connecting the same two nodes but with opposite directions can be used to represent relationships that can operate in either direction (6).

If the state of a system may be described in terms of two sets of variables satisfying the following criteria: (a) through variables whose sum is zero at the

* Is it possible to cross, in turn, each of seven bridges connecting two islands and the banks of a river, as shown in Fig. 2, and return to the starting point without crossing any of the bridges twice? (No; for proof, see Ref. 11).

** Numbers in parentheses refer to the list of references.

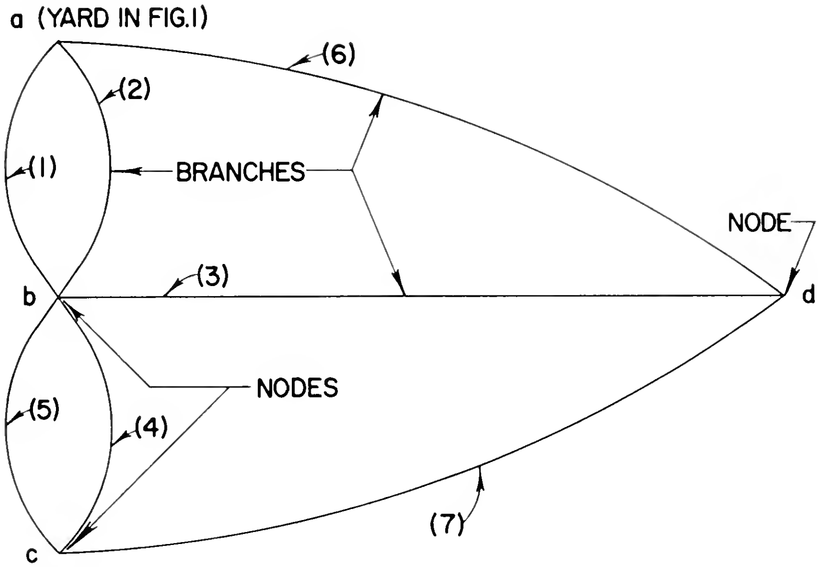

FIG. 3 GRAPH OF THE PROBLEMS IN FIG. 1 AND FIG. 2

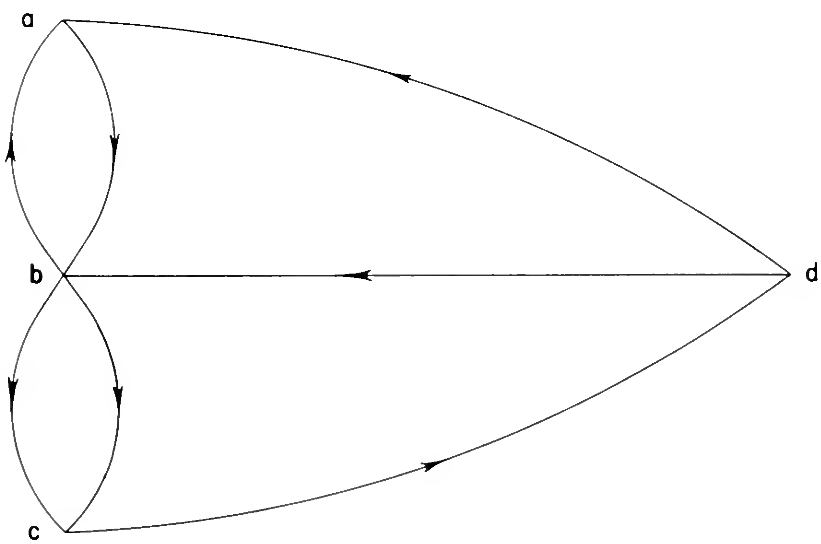

FIG. 4 DIRECTED GRAPH

nodes of the system graph and (b) across variables whose sum around any closed circuit of the graph such as aba, abcda, or bcdb in Fig. 3 is zero, the system will perform in a definite way for a given set of conditions and may be analyzed by network theory. Examples of systems where these conditions exist, along with the variables involved follow:

System	*Through Variable*	*Across Variable*
Electrical Network	Current	Potential
Hydraulic Network	Flow	Head or Pressure
Structural Frame	Loads	Displacement

(Electrical analogies of mechanical or other systems have the same characteristics as other electrical networks.)

Considering the hydraulic network, these principles may be illustrated as follows:

(a) The total flow into any intersection (node) in the system equals the flow out of the intersection.

(b) The head loss between two points in the system is the same regardless of which path is followed between the points.

Although there are certain similarities between a railroad system and a hydraulic network, the analysis of the railroad system is much more complex. A few of the reasons for the greater complexity are:

(a) The system has multicommodity flows and flow of products from A to B may occur at the same time as flow of products from B to A over the same path.

(b) Over a given period of time, the system is not necessarily in equilibrium.

(c) The problem usually consists of optimizing the performance of the system rather than in determining the manner in which the system will be forced to perform by physical laws.

(d) The system consists of sub-systems, e.g., transportation, maintenance, crew flows, locomotive flows, etc., one of which may be degraded by a change improving another.

(e) The system is not self-contained and is affected by external changes in the economic system and in other transportation systems which would have to be considered in a complete analysis. Nevertheless, network analysis has been applied to the study of railroad systems (1, 7, 8).

The network simulation developed by Allman (1) has been used by the St. Louis–San Francisco Railway (8). The nodes of the network are the terminals and the arcs the main-line tracks. Twenty-nine terminals (nodes) are represented in this network simulation. The use of this model has resulted in important changes in train schedules on the Frisco. The model is soon to be used to evaluate the impact on operations and service of long vs. short trains. A study of the economics of blocking in Springfield, Mo., for direct connection to junction roads at St. Louis, Mo., rather than the present policy of switching at St. Louis for connection is being conducted.

Trailer-on-flat-car and container-on-flat-car operations can be analyzed as separate subsystems within the framework of the total railroad system since the cars and terminal facilities used in these operations are not used for other traffic. The reduced number of origins, destinations and car types involved will result in a less complex system which could be analyzed before development of capability to analyze the complete railroad system. In addition, the highly competitive nature of the traffic involved is a strong argument for optimizing these operations as rapidly as possible instead of waiting until the complete system can be analyzed.

One of the most useful applications of networks is describing the relationship between operations which must be performed in a logical or time sequence. The flow chart used in computer programming is actually such a network with the operations being performed at the nodes. Within the past decade, scheduling techniques such as Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) have developed into highly effective procedures for analyzing systems of activities as networks with branches representing operations and nodes representing points in time (2, 9, 12, 13). These techniques have been applied to such railroad problems as the construction of bridges, stations, yards, terminal facilities, line changes, CTC installations and grade separations and the planning of LCL freight and express services, commuter services and car control systems.

Although detailed Critical Path scheduling for a large project requires a computer to perform the necessary calculations in a reasonable length of time, the manual construction of the Critical Path network for a small project or of a simplified network for a larger project is of great assistance in demonstrating the relationships between various parts of the project. This is an example of the value of network analysis in identifying and defining problems. These initial steps must be taken before attempting any quantitative solution.

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Report of Committee 14—Yards and Terminals

°H. J. McNally, *Chairman*
°C. E. Stoecker, *Vice Chairman*
°A. E. Biermann, *Secretary*
°W. P. Buchanan†
°G. H. Chabot
°B. E. Buterbaugh
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D. E. Turner
B. H. Voor, Jr.
Howard Watts, Jr.
W. E. Webster, Jr.
D. W. Wessels
P. C. White

Committee

† Died May 4, 1967.
(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairman, and those designated by asterisks constitute the Engineering Division, AAR, Committee 14.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Two recommendations for revision of Chapter 14 of the Manual will be presented for adoption in Part 2 of the December Bulletin.

2. Classification yards, collaborating as necessary or desirable with Committee 16.

   The specific subject under study this year was "Factors to be Considered in Revision of a Manual Yard to an Automatic Retarder Yard." A report on this subject is not ready at this time, but study will be continued during the coming year.

3. Scales used in railway service, collaborating as necessary or desirable with Committee 18.
Progress report on "Belt Conveyor Scales" presented as information .. page 145

4. Description of new facilities for storing and rehandling of taconite at Duluth, Minn., and Superior, Wis.
Final report, presented as information .... page 147

5. Description of an English hydraulically operated yard for controlling car movements in classification yards.
Final report, presented as information .... page 158

6. Expediting passenger handling in stations and terminals.
Final report, presented as information .... page 166

The Committee on Yards and Terminals,

H. J. McNally, *Chairman.*

AREA Bulletin 609, November 1967

Willard Paul Buchanan
1905-1967

Willard Paul Buchanan, supervisor of scale inspectors and erectors for The Pennsylvania Railroad and a member of Committee 14 since 1953, died on May 4, 1967 at Altoona, Pa.

Mr. Buchanan was born on October 12, 1905 at Altoona, to parents Frank Buchanan and Etta (Speer) Buchanan. On April 25, 1932, he married Mabel McDowell at Baltimore, Md. He is survived by his wife, a daughter, Mrs. Robert Bouffard, and three granddaughters.

Mr. Buchanan started work as a messenger for the Pennsylvania in 1922 and was employed by that company until the time of his death. He advanced through the positions of machinist, assistant gang foreman, scale erector, scale inspector, superintendent of scales, and supervisor of scale inspectors and erectors.

At the time of his death Mr. Buchanan was president of the Altoona Engineering Society and Trustee of the Ward Avenue Presbyterian Church. He was also a member of the Masonic Order Scottish Rite and of the National Scale Men's Association.

Mr. Buchanan joined the AREA in 1953 and was soon actively engaged in that part of Committee 14's work which pertains to scales. During the past seven years he had served as chairman of the Scales Subcommittee. He contributed generously to the work of the committee and was highly respected for his wise counsel and willingness to accept heavy assignments in developing scale information important to the membership of the AREA. His associates will long remember his pleasant personality.

Report on Assignment 3

Scales Used in Railway Service

Collaborating as Necessary or Desirable with Committee 18

J. L. Dahlhot (chairman, subcommittee), A. E. Biermann, R. E. Bredberg, A. L. Carpenter, G. H. Chabot, M. K. Clark, J. A. Comeau, E. H. Cook, B. E. Crumpler, H. L. Dalziel, V. F. Demarais, C. M. Frazier, D. C. Hastings, I. M. Hawver, F. A. Hess, J. E. Hoving, C. F. Intlekofer, D. B. Kendall, A. S. Krefting, V. L. Ljungren, L. L. Lyford, H. J. McNally, C. H. Mottier, H. Phypers, W. H. Pollard, B. H. Price, A. E. Robinson, L. W. Robinson, J. F. Scheumack, C. W. Silver, E. B. Sonnheim, C. E. Stoecker, T. W. Toal, J. N. Todd, Howard Watts, Jr., D. W. Wessels.

Your committee presents the following report on belt conveyor scales as information with a recommendation that this subject be continued.

Belt Conveyor Scales

With the increased volume of freight traffic, and the speeds with which this traffic must be moved, the railroads are actively seeking ways to reduce delays in the forward movement of their trains. One of the more important tasks associated with freight movements is the weighing of the material being handled, and the delays usually associated with this operation in the terminal can be substantially reduced through the utilization of a well placed, high-speed weighing system. Many such systems are now in use and are so arranged that a car can be weighed without additional handling during a humping or a flat-yard switching operation.

Technological advances in the scale industry have enabled a high degree of weighing precision without impeding the forward movement of freight traffic. However, costs involved in the placement of such systems are such that economic justification for the placement at remote points along the right-of-way is difficult to establish.

Because of this, the trend seems to point toward the abolition of the older wayside weighing stations, with the larger portion of the weighing being directed to the terminal points on the railroad. While this operational plan may result in a substantial reduction in weighing costs and equipment delay in general, it will often result in the increased need for reduction of overloads of bulk materials at the terminal weighing point, or the back-hauling of the material to the point of origin for load reduction. In either event, the cost and delay of doing so may overshadow the wayside weighing cost and delay; increase the turnaround time of the rolling equipment, and cause customer discontent in having his shipment delayed because of a condition over which he had little or no control at the time of loading.

With the introduction of the unit train, the railroads realized that unnecessary terminal congestion and delay would result in moving the unit train into the larger classification yards, and since no purpose would be served in doing so, arranged to by-pass these yards where track conditions would permit.

In doing so, a large portion of the bulk material hauled in unit-trains is now moved without the benefit of having been weighed at the loading point, or in transit, since few of the shippers have appropriate weighing equipment to determine weight values at the point of origin, and the railroad is deprived of the use of their highspeed scales in the terminals since they do not generally enter the yards en route to destination.

A large portion of the material hauled by the railroads is in bulk form and is loaded into open-top railroad cars by belt conveyors. Most solid bulk material that can be moved by belt conveyor can be weighed on the belt. It is therefore reasonable to assume that through the utilization of a proper belt conveyor weighing system, bulk materials can be handled under actual weight values rather than average weight agreements such as now exists in many bulk-commodity shipments.

The belt conveyor weighing system is not generally considered to be an acceptable method of commercial weight determination in the United States; however, there are many such installations that have been formally approved for specific applications. The applications are generally related to the weighing of crude ore, gravel, sand, crushed stone and coal, etc., and official weight agreements based on the weights derived therefrom on both in-bound and out-bound shipments have been negotiated.

The belt weighing system measures "net weight" and a probable one-half percent variation in the net weight of a quantity of bulk material, providing this precision is attainable, does not appear to be out of line with the weighing requirements for such materials, particularly when compared to track-scale weights where the net weight of the commodity is calculated to be the numerical difference between the track scale gross weight, and the car's marked tare.

The weight of most solid bulk materials will be seriously affected when exposed to inclement weather, and the resulting net weight of the commodity when track-scaled will appear to be greater than its true value.

A belt conveyor scale is an appliance for weighing material carried on a belt without adversely affecting either the speed or continuity of the process. This is accomplished through the continuous integration of two measurable quantities—a measure of conveyor loading in terms of pounds per lineal foot of conveyor belt, and a measure of belt speed in feet per minute of belt travel. This provides a measure of pounds per hour and thus a measure of total pounds flowing per given elapsed time period.

Manufacturers of belt conveyor scales generally claim, with stringent installation requirements, an inherent weighing capability of 99.50 percent accuracy for their product. Actual tests reveal that errors far in excess of 1 percent are often encountered. But in many instances where large errors do exist, the error is not related so much to the scale's hardware as to its location in the conveyor system, the installation and quality of maintenance, the efficiency of the belt takeup device, the condition of belt loading, and/or other conditions which are incompatable with good belt conveyor weighing practice.

Through the utilization of a good belt conveyor scale in his loading operation, the shipper can realize instant availability of net weight information for waybilling and invoicing purposes, an opportunity to acquire contracts for many tons of material in which he must meet the requirements of delivery, a method by which he can load railroad equipment by actual net weight rather than by visual capacity which will result in better utilization of the rolling equipment available to him, and a comparatively small initial monetary investment to acquire the system.

To the railroad, this shipper's weighing system could result in fewer cars being required to move a given quantity of material, shorter turnaround time for the equipment used in the operation, actual tonnage values which would preclude the need for an average weight agreement upon which waybill charges are made, and a probable improvement in customer relations through the use of actual rather than estimated weight values.

The receiver of this commodity could also enjoy certain benefits from this scale in that more efficient material flow control could be maintained in his operation, and more realistic inventory records could be maintained through the use of actual net weight receiving information.

While widespread use of belt conveyor scales is not in evidence at this time, it is expected that the number of operational systems will show a substantial increase in the near future, and a continuation of this study will serve a purpose in providing a better understanding of how the system functions, and how it should be applied and used to enable it to perform within the parameters for which it was designed.

Report on Assignment 4

Description of New Facilities for Storing and Rehandling of Taconite at Duluth, Minn., and Superior, Wis.

C. F. Intlekofer (chairman, subcommittee), R. O. Balsters, H. R. Beckmann, A. E. Biermann, W. O. Boessneck, G. H. Chabot, H. P. Clapp, M. K. Clark, J. A. Comeau, W. E. Corbet, B. E. Crumpler, H. L. Dalziel, V. F. Demarais, T. R. Dushel, C. M. Frazier, W. H. Goold, H. R. Hall, J. E. Hoving, D. B. Kendall, A. S. Krefting, C. J. Lapinski, V. L. Ljungren, G. W. Mahn, Jr., A. Matthews, Jr., H. J McNally, B. G. Packard, H. L. Pepper, Jr., W. H. Pollard, B. H. Price, L. W. Robinson, C. E. Stoecker, L. L. Tameling, J. J. Tibbits, A. J. Trzeciak, Howard Watts, Jr., D. W. Wessels, P. C. White.

Your committee submits as information, with the recommendation that the subject be discontinued, a description of new facilities for the storing and rehandling of taconite at Duluth, Minn., on the Duluth, Missabe & Iron Range Railway, and at the Allouez Ore Docks of the Great Northern Railway, Superior, Wis.

DULUTH, MISSABE & IRON RANGE TACONITE STORAGE FACILITY, DULUTH, MINN.

The DM&IR has completed construction and is operating the first stage of its Lakehead facility designed to provide storage of taconite pellets and other iron ore products processed during the off-navigation season. It is situated in West Duluth on the east side of the railroad's ore docks in the area of Ore Dock No. 6, to and including its former coal dock. The second stage, similar to the first-stage facility, is being developed and some segments are under construction.

Lakehead has a total area of 120 acres, of which 40 acres are being utilized by the first stage; the remainder are available for expansion. The facility is designed to be expanded in several stages from an initial storage capacity of 2.2 million tons of pellets to an ultimate capacity of 10 million tons.

The ultimate plan provides for stockpiles to be situated adjacent to parallel conveyor systems, each designed to operate independently and capable of stockpiling or reclaiming 2240 tons per hour. The initial facility has one such system, with space for expansion to three systems, giving an ultimate capacity of 6720 tons per hour. This arrangement will permit the handling of up to three different products simultaneously, or fast recovery of a single product at a 6720-ton-per-hour rate.

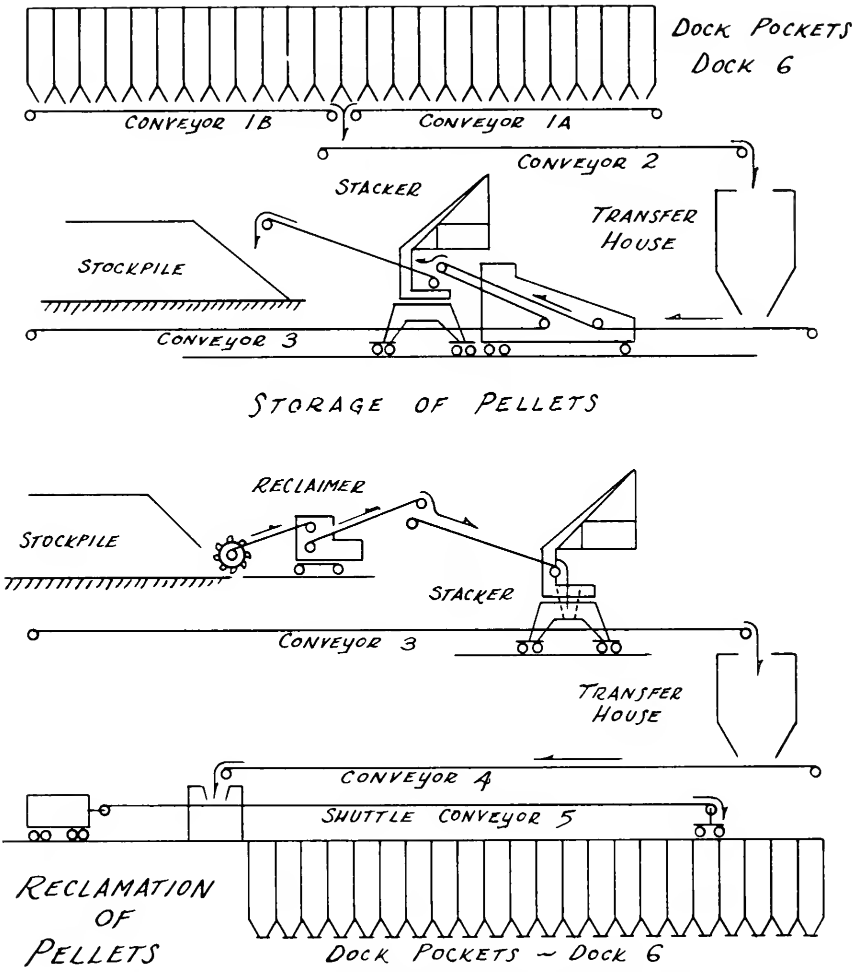


Fig. 1—Diagram of DM&IR Lakehead storage facility operation.

The railroad now operates two ore docks, No. 5 and No. 6, on St. Louis Bay, each 2304 ft long and containing 384 pockets, with a capacity of 300 tons per pocket. A part of dock 6 has been incorporated into the new storage facility to take advantage of the most desirable combination of surge, storage and gravity ship-loading. The system of conveyors and stockpiles is shown in Fig. 1.

The new facility will operate all year round. Ore products, produced on the Mesabi Iron Range, can be shipped directly to the Duluth docks on a daily production basis, with summer production being loaded directly from cars into dock pockets for shiploading in the same manner as natural ores and winter production dumped into specially equipped dock pockets and then transferred to stockpile by a conveyor system. During the following navigation season, this material is reclaimed from stockpile by a bucket-wheel reclaimer and conveyed to the top of the dock where it is deposited in dock pockets for shiploading.

Project Commenced in 1964

The initial site development contract was awarded in October 1964. This contract consisted of clearing the area, removal of undesirable swamp materials and backfilling with selected material obtained by dredging from St. Louis Bay to an elevation of 6 ft above the mean water level of Lake Superior. The material obtained from the borrow area was a clean, uniform sand containing from ½ to 2 percent passing a No. 200 sieve, with 100 percent of the material passing a No. 4 sieve. Embankments were compacted to a density of 97 percent with the upper 2 ft being compacted to 100 percent of maximum density, using vibratory compaction equipment. The upper 4 in of the compacted sand subgrade were stabilized by the addition and mixing of 7 percent by weight of mineral filler and 2½ gal per sq yd of asphalt emulsion. The entire stockpile area was then finished with a 2-in plant-mix bituminous surface.

A 15-ft-high berm, 1600 ft long with a 50-ft-wide top, was constructed through the center of the stockpile area to support the stockpiling-reclaiming conveyor and to elevate the stacker above the stockpile area, thereby gaining stockpiling capacity. The side slopes of the stacker berm were stabilized and surfaced in the same manner as the stockpile base area. The top of the berm was dressed with 2 ft of mine tailing, which was used also as ballast for the stacker tracks and supports for the stock-piling-reclaiming conveyor.

Receiving Dock Pockets

The inner one-third of the east side of Ore Dock 6 was converted to provide a winter receiving area equal to 64 pockets, each with a capacity of four high-side cars, for a total capacity of 256 cars. The pockets provide the surge necessary to permit scheduling of unit trains to meet customer production requirements, while maintaining a uniform daily stockpiling rate. Spouts and chutes on the receiving pockets were removed and the pockets equipped with specially designed hopper-type bin fronts and air-operated feeder gates. The feeder gates control the flow of pellets onto conveyors, which move the pellets longitudinally along the dock to a transfer point, where they are fed to the 1600-ft stockpiling belt on top of the stacker berm. They are then tripped off this belt onto the luffing-type stacker boom for placement onto stockpile.

The entire conveyor system is equipped with 48-in belting and 35-deg troughing idlers. Conveyors operate at speeds from 500 to 550 ft per min. All conveyors are equipped with fully enclosed, force-ventilated motors and solid-state controlled torque drive controls.

The materials' stacker is equipped with a 176-ft luffing boom designed to rotate through an angle of 270 deg. Operating on the 15-ft-high berm, the stacker is capable of building a stockpile 75-ft high. The stacker operates on two sets of parallel standard-gage railroad tracks constructed of treated ties and 155-lb rail on 30-ft track centers. The stockpiling-reclaiming conveyor, which both feeds and receives material from the stacker, is also supported on railroad track. This arrangement permits the stacker track and conveyor system to be surfaced and lined with standard railroad maintenance equipment.

Bucket-Wheel Reclaiming

During the reclaiming cycle the stacker boom is lowered to 12 ft above the stock-pile base and the belt system reversed. Stockpiled materials are reclaimed by bucket-wheel and deposited in the receiving hopper on the outer end of the stacker boom. The pellets are then conveyed to the top of the dock.

The bucket-wheel reclaimer is an electrically operated crawler-mounted machine. During normal reclaiming operations, the machine operates on commercial electric power obtained from a receptacle mounted on the outer end of the stacker boom. It is also equipped with a diesel-electric generating unit, which provides power to propel the unit from one area to another. The machine has a reclaiming capacity of 3080 tons per hour, is 90 ft long and weighs 300,000 lb.

Material received at the top of the dock is fed through a transfer chute to a shuttle conveyor mounted on standard-gage flanged wheels, and designed to operate on the existing Dock 6 track system. The shuttle is electrically powered, self-propelled, and can deposit reclaimed material in any one of 192 dock pockets for gravity loading into vessels.

Control of Entire Facility

The entire operation is controlled from a console in the service building at the west end of the storage facility. The console operator remotely controls the feed gates on the 64 receiving pockets, dumping material in any desired pocket sequence. The materials stacker is fully automated with boom position and location remotely controlled from the console during stockpiling. During the reclaiming operation, the boom position and location are remotely controlled from the cab of the bucket-wheel reclaimer. Operation of the entire conveyor system, in both reclaiming and stock-piling, is monitored from the control console through the use of telemetering and other detection equipment.

Materials recovered from storage are weighed on a mechanical-type belt scale situated on the reclaiming conveyor. The scale is equipped with a remote read-out situated on the control console.

An auxiliary standby conveyor system assures uninterrupted recovery of materials in case of an emergency. The system consists of a rail-mounted receiving hopper operating on the stacker track system and positioned over the stockpiling-reclaiming conveyor equipped with a 24-ft belt feeder and front-end loader dump hopper. The system is designed to be used as a bypass for either the materials' stacker or the bucket-wheel reclaimer. It has an operating capacity of 1120 tons per hour, can be fed by either front-end loader or bucket-wheel reclaimer, and is rubber-tire-mounted for complete mobility. It can be used also to load material from stockpile directly into railroad cars.

Equipment for Continuous Operation

The entire facility is equipped with mercury-vapor lighting for 24 hr per day operation. A complete communications and loud-speaker system assures good communication between all operating and maintenance personnel. Final cleanup of the stockpile areas is performed by power-operated sweepers and 4-yd front-end loaders.

GREAT NORTHERN TACONITE PELLET TRANSFER FACILITY, SUPERIOR, WIS.

In the spring of 1967, the GN put into operation a taconite-handling facility at its Allouez Ore Docks.

A unit train hauls the pellets from two new taconite plants in Minnesota's Mesabi Iron Range to the bulk handling facility at the head of the lakes where the pellets are stockpiled in the winter or conveyed directly to dock pockets for delivery to the ships in the shipping season, the latter being from early April to early December. One unit train, hauling two-hundred 75-ton bottom-dump hopper cars, makes a round trip daily from the Range to Allouez. (See map, Fig. 5.) Plant hoppers load the train in motion in about 3 hr with 15,000 tons of pellets. On arrival at Allouez, the engine spots the first two cars over the tandem unloading hoppers. The engine is then uncoupled and the door-opener operator starts the "indexer" to move the train over the hoppers at the rate of 2 cars every 3 minutes.

After two cars are properly positioned over the track hoppers and held fast, a signal from the wheel lock starts both door-opening devices, which will activate the door-operating mechanism and open the doors. An adjustable timer provides a signal to the devices which closes the door. The swinging of the door opener into the clear initiates the next train push index.

After dumping, the pellets are transported from the track hoppers by a belt conveyor system designed to handle 3000 tons per hour. This system can place the material in a stockpile or deliver it to the dock pockets on Dock No. 1. This dock, built in 1927, is 2244 ft long with 188 pockets on each side. Two tracks were removed from the west side of the dock to permit placement of the conveyor and tripper which will place pellets in the east pockets.

Conveyors

The system of conveyors from hopper to dock is shown in Fig. 2. A list of the conveyors, including their functions, is as follows:

(1) Feeder conveyors, No. 1A and No. 1B, bring pellets from under hoppers and deposit them onto the tunnel conveyor.

(2) Tunnel conveyor, No. 2, conveys material from underground to above ground and onto the storage conveyor.

(3) Storage yard conveyor, No. 3, is on a berm through the storage yard, rises over the loop track and deposits the pellets onto the overland conveyor.

(4) Overland conveyor, No. 4, carries them over other railroads and streets and drops them into the 200-ton surge bin where they are released to the weigh conveyor.

(5) Weigh conveyor, No. 5, deposits the pellets onto the dock conveyor.

(6) Dock conveyor, No. 6, extends the length of the dock and, with the use of a tripper, drops the taconite pellets into dock pockets.

The tripper on conveyor No. 3 is capable of delivering material back to conveyor No. 3 for direct loading to the dock pockets or delivering material to the stacker boom, conveyor No. 3A, for stockpiling. The switchover from stacking to direct loading is accomplished by disengaging a tow bar, releasing the tripper trailer, driving the stacker structure about 15-ft from the tripper trailer, re-engaging the tow bar, and lowering the tripper head pulley to a position where it can discharge back onto conveyor No. 3.

The switchover from direct loading to stacking operations is accomplished by disengaging the tow bar, elevating the tripper boom conveyor, driving the stacker toward the tripper trailer, re-engaging the tow bar, and lowering the tripper frame

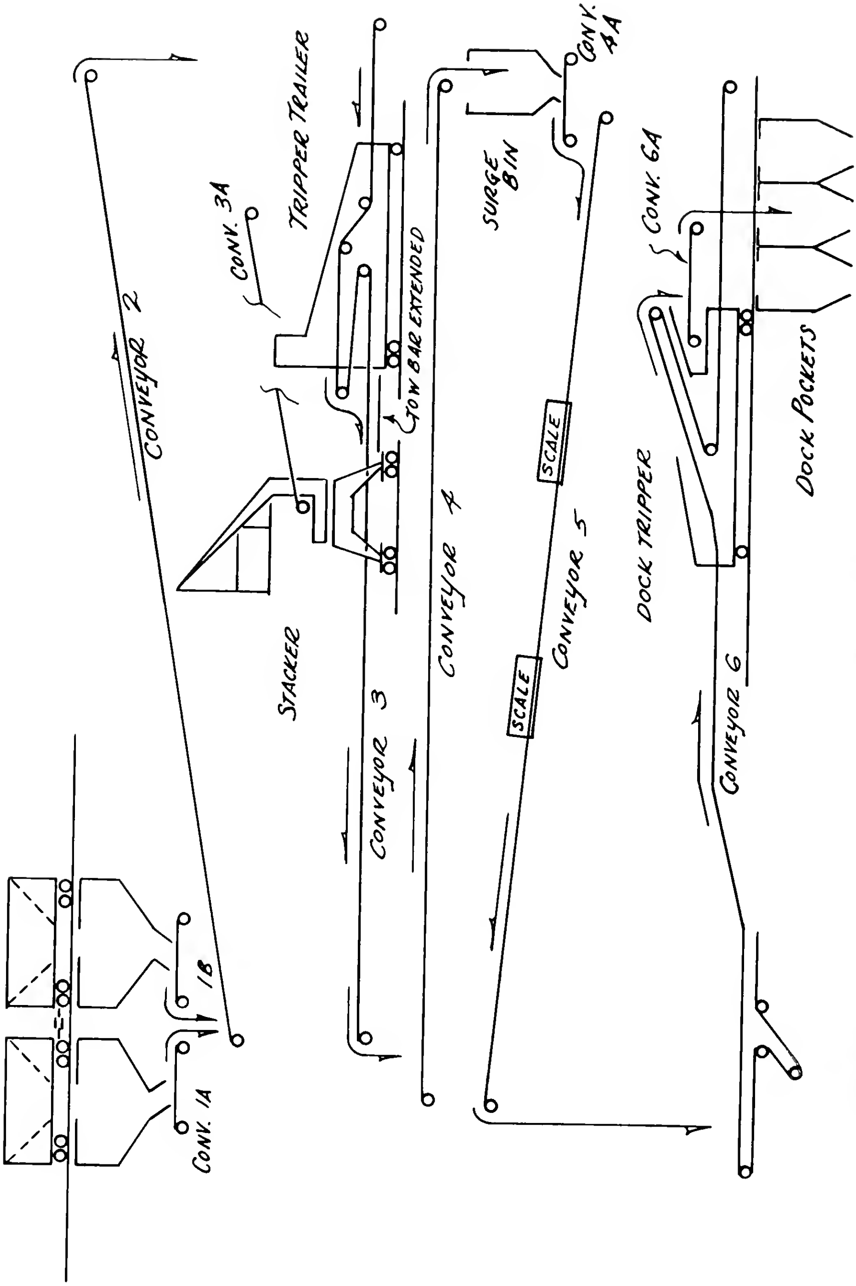


Fig. 2—Direct transfer.

into the securing hooks, so that it can discharge onto conveyor No. 3A. During the shipping season, the tripper is lowered with the bar connection extended, as both direct transfer and reclaiming are carried out from this position. Each dock pocket can hold approximately 325 tons of pellets. Shiploading is performed by means of pocket chutes.

When direct loading pellets, the dock tripper operator starts and stops the conveyor system as required. In addition, automatic devices are provided to permit emergency stopping or sequence starting and stopping. The operator must move the tripper and operate the batch control to satisfy the required loading pattern.

Dock pockets can be loaded at an average rate of 3360 tons per hour from trains. This provides approximately 30,000 tons per day of dock pocket loading to satisfy the filling of two ships averaging 15,000 tons each.

Normally, the weigh-feeder under the 200-ton surge bin is set to deliver a measured quantity of 300 tons and then shut off the feeder conveyor automatically. The operator can also set the feeder to shut off with a trimming load of 100 tons by means of a selector switch. At the beginning of each sequence, the dock office punches into the tape the record date, whether direct unloading from train or reclaiming from stockpile, and the source. The dock tripper operator dials in the pocket number and punches the weight of batch desired. These latter two items are transmitted to the tape to make up the complete data for each pocket of ore. The tape equipment is located in the dock office. The scale can be reset at the beginning of each sequence and totalizes as it weighs in addition to identifying the weight in each pocket. The totals are the difference between the last recorded total and the next total.

The system includes equipment for batch sampling. The sampler is located at the discharge end of conveyor No. 5. Samples of each batch are taken and cataloged by an operator furnished by the shipper. This operator is furnished a copy of the read-out data from the dock office which is correlated with the samples so as to identify each sample with a pocket number.

The dock-tripper operator calls for a measured batch and positions the tripper over a 12-ft-wide pocket. The operator can move the tripper and conveyor boom to distribute the load in the pocket. All belts in the system normally run continuously except for the weigh-feeder which starts on signal from the dock tripper operator and shuts off automatically from scale signal. The operator must provide enough gap on the dock conveyor belt behind the measured batches to allow sufficient time to move the tripper without discharging material between pockets or into previously loaded pockets.

The 200-ton surge bin behind the dock conveyor allows for 4 min of zero discharge when being fed at the 3000-ton-per-hour rate. A high-level probe automatically stops all conveyors behind the surge bin when it is filled. A signal light is provided in the dock-tripper cab to indicate zero material on the weigh-feeder on completion of a measured batch. When less than a preset batch is received from the surge bin, the weigh-feeder (which stops before it is completely empty) will resume running when a suitable level is re-established in the surge bin. The batch control will retain the accumulated weight and continue totalizing.

If desired, the dock-tripper operator can signal to enter the weight of the incomplete batch and order a new batch. The dock-tripper operator knows of the partial batch by means of the signal light and can hold the tripper in the pocket until the material flow resumes and pocket filling is completed. The dock tripper can discharge material into pockets when traveling inshore or offshore.

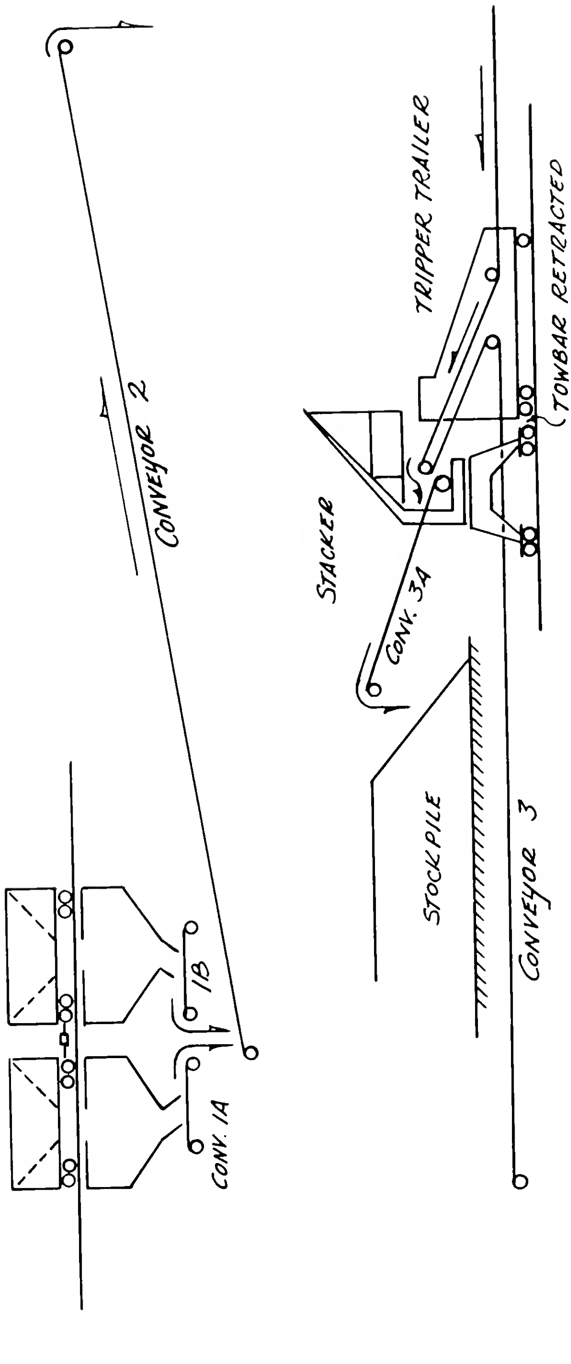


Fig. 3—Stacking.

All conveyors run a a single fixed speed except for belt-feeder conveyor No. 4A, which is run at half speed for reclaim. The dock tripper, controlled by the operator, travels at a single speed intermittently when loading across the pocket face.

Stacking Operation

A sketch of the stacking operation is shown on Fig. 3. To stock pellets, the material flow is from the track hoppers onto feeder conveyors Nos. 1A and 1B, tunnel conveyor No. 2, yard conveyor No. 3, and over the tripper to the stacker boom conveyor No. 3A. The stacker operator positions the boom to properly form the storage piles. The piles can be started with the luffing boom which is lowered to a position close to the ground to limit material drop. The buildup of the pile to the 50-ft-high maximum can proceed in various ways, best determined by the operator, to provide the necessary number of piles, equipment clearance, minimum segregation and degradation and proper separation of pellet types.

Normally, the piles will be formed from the outside in and from north to south, with the stacker retreating from the pile. This procedure is recommended to provide boom clearance over high piles and the least sacrifice of pile length due to stacker tripper space requirements along yard conveyor No. 3.

Reclaiming Operation

A sketch of the reclaiming operation is shown on Fig. 4. Reclaiming of pellets will be by means of the bucket-wheel reclaimer at an average rate of 1680 tons per hour. The wheel operator determines reclaiming procedures that are best suited to the particular requirements. The operation of the wheel must be coordinated with that of the stacker; the stacker operator must position the stacker boom to suit the wheel operator's movements. The operators communicate by radio. The bucket wheel discharges the reclaimed pellets into a receiving hopper at the end of the stacker boom.

The stacker boom conveyor No. 3A is run in a reverse direction when reclaiming. The material from the stacker boom is reclaimed through an opening in the center of the stacker slewing ring and deposited through stone boxes onto an impact section carried with the stacker. The stacker conveyor No. 3A, yard conveyor No. 3 and conveyor No. 4 to the bin are designed for 3000 tons per hour and are capable of taking wheel load surges. The wheel conveyor belts are designed to carry an average of 1680 tons per hour and have sufficient surge capacity to accommodate wheel-type surges.

The bucket-wheel excavator is diesel powered and hydraulically operated. The reclaimer operator must stop reclaiming operations when the loadout conveyors stop. The stacker will travel at a single speed of approximately 60 ft per min and will move in either direction on signal from the stacker operator.

A minimum of three operators and a foreman can operate the facility during the shipping season. In the winter season, it will function with two operators and a foreman.

The facility is designed so that it can be expanded to handle double the initial capacity of 4.6 million tons per year. The expansion would be accomplished by doubling the stockpile area and adding a shuttle conveyor to extend from the end of the stacker conveyor No. 3A to the extreme limits of the stockpile. It would also be necessary to acquire either another wheel reclaimer of 1500-ton capacity or to replace the initial 1500-ton-capacity wheel reclaimer with a 3000-ton machine.

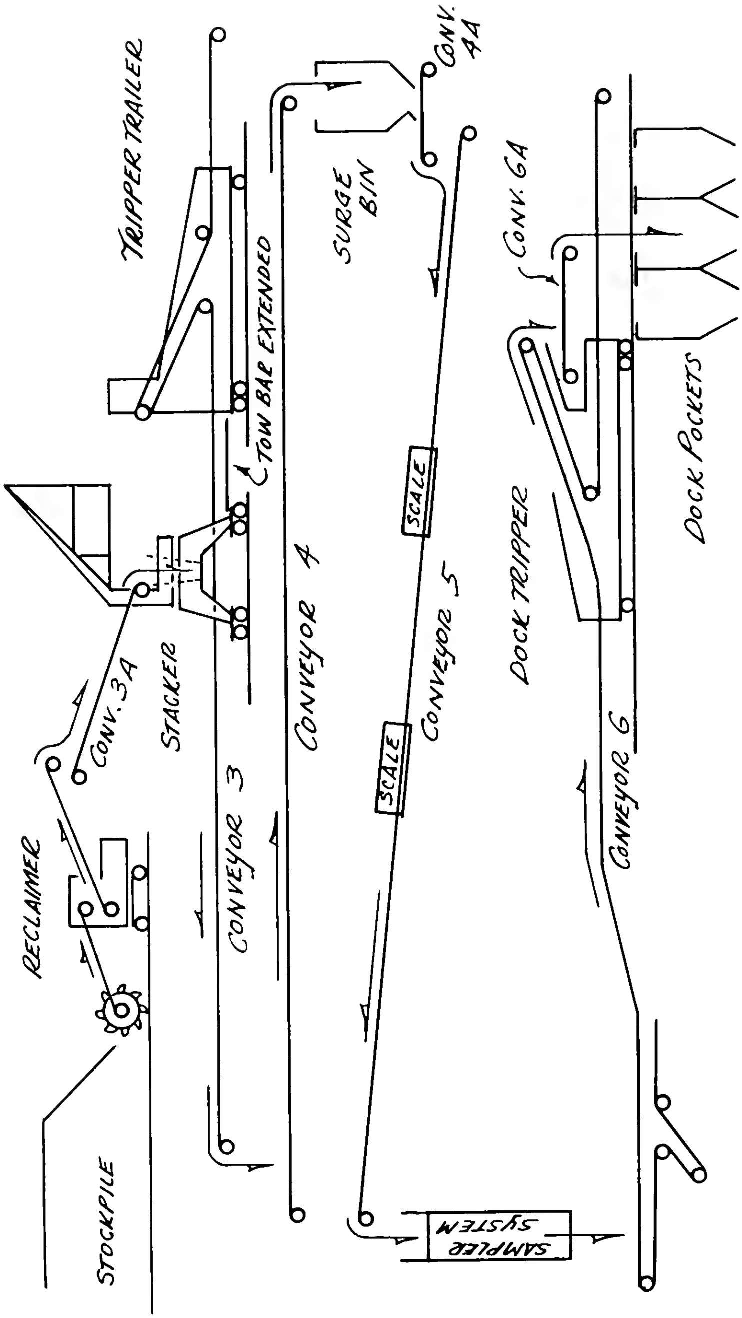
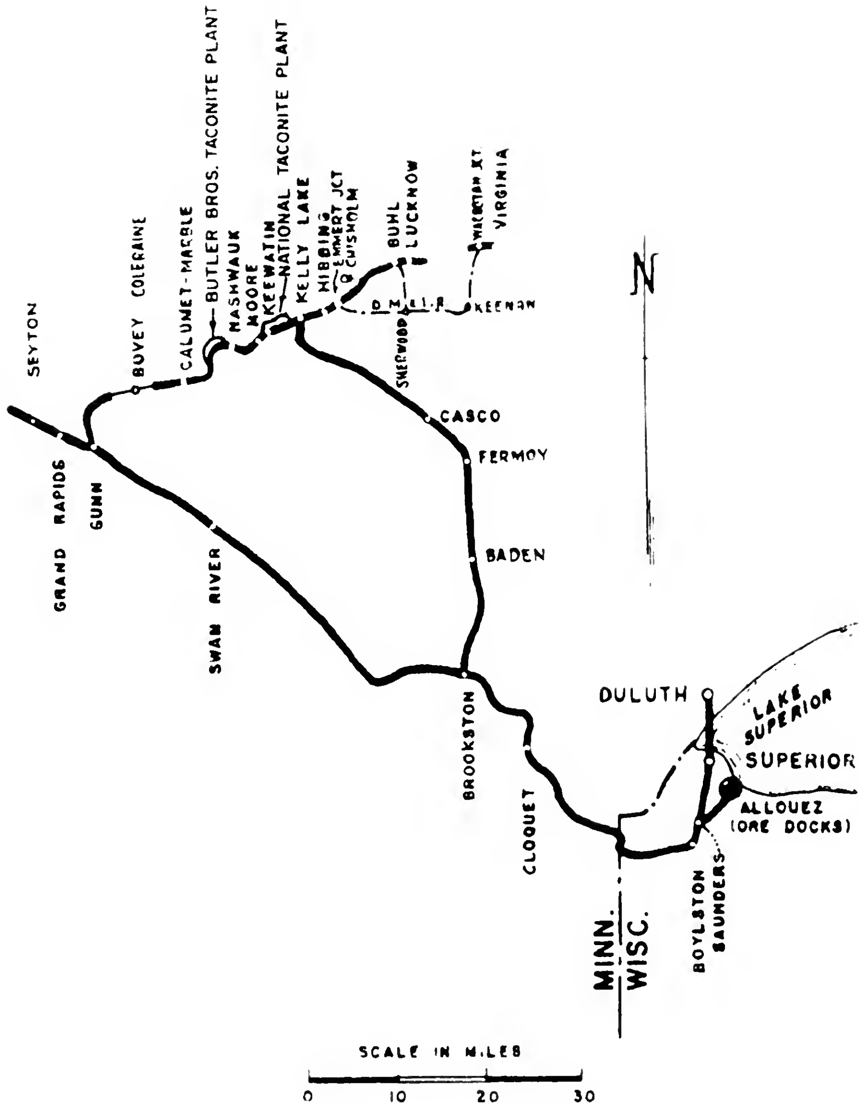


Fig. 4—Reclaim.



NATIONAL TACONITE
Keewatin to Allouez via Gunn 108.9 miles
Alleouz to Keewatin via Casco 103.9 miles

BUTLER TACONITE
Nashwauk to Allouez via Gunn 103.3 miles
Allouez to Nashwauk via Casco 109.5 miles

Great Northern Railway
TACONITE OPERATIONS
Mesabi Division

Fig. 5.

Fig. 5 shows the location of the taconite plants on the Mesabi Range and the rail lines to the ore docks at Allouez. Table 1 lists pertinent data for the movement and storage of taconite pellets by the Great Northern Railway.

TABLE 1—TACONITE FACTS

At Nashwauk, Minn.	
Production date	March 1967
Production capacity (long tons per year)	2,000,000
Pellet size (inches)	11/32
Pellet iron content (percent)	65
Pellet density (pounds per cubic foot)	135
Rate of loading per hour (tons)	6,000
At Keewatin, Minn.	
Production date	May 1967
Production capacity (long tons per year)	2,400,000
Pellet size (inches)	11/32
Pellet iron content (percent)	65
Pellet density (pounds per cubic foot)	135
Rate of loading per hour (tons)	6,000
Unloading—Unit Train Statistics	
Number of cars	200
Car capacity (tons)	75
Type of bearing	Roller
Unloading	Drop bottom
Unloading and Storage Facility, Allouez, Wis.	
Capacity of stockpile area (tons)	2,200,000
Train unloading capacity (long tons per hour)	3,000
Stockpile reclaiming capacity (long tons per hour)	1,500
Capacity Dock No. 1 (tons)	112,800

Report on Assignment 5

Description of an English Hydraulically Operated System for Controlling Car Movements in Classification Yards

JACK SUTTON (chairman, subcommittee), M. H. ALDRICH, R. O. BALSTERS, H. R. BECKMANN, A. E. BIERMANN, A. L. CARPENTER, G. H. CHABOT, H. P. CLAPP, E. H. COOK, W. E. CORBET, B. E. CRUMPLER, W. H. GOOLD, H. R. HALL, WM. J. HEDLEY, C. F. INTLEKOFER, C. J. LAPINSKI, E. T. LUCEY, A. MATTHEWS, JR., H. J. MCNALLY, M. B. PARKER, H. L. PEPPER, JR., W. H. POLLARD, L. J. RIEKENBERG, J. F. SCHEUMACK, E. B. SONNHEIM, C. E. STOECKER, L. L. TAMELING, J. J. TIBBITS, L. G. TIEMAN, T. W. TOAL, A. J. TRZECIAK, HOWARD WATTS, JR., P. C. WHITE.

Your committee submits, as information, the following report on a new system for control of car speeds in a classification yard, with the recommendation that the subject be discontinued.

At their Tinsley Marshalling Yard near Sheffield, British Railways have introduced an entirely new system for controlling the speed of free-rolling cars. The new system, devised by Dowty Mining Equipment Ltd., is designed to effect continuous speed control from the crest of the hump to the coupling point. Small hydraulic devices installed at intervals along each track adjust the speed of the free-rolling cars. The devices are able to retard or accelerate the cars to pre-set track speeds.

There are two major benefits to be realized from an effective, continuous speed-control system. First, damage to cars and contents can be reduced by elimination of overspeed coupling. Second, humping efficiency can be gained if all cars keep rolling to their coupling points. There is then no need to stop humping to send engines into the classification tracks to push down stalled cars. These are the objectives of the new speed-control system.

The Yard Layout

At Tinsley the 53 main classification tracks are arranged in 8 groups fanning out from a single hump lead. One of the main classification tracks is used as a lead to a secondary hump which fans out in 4 groups to a further 25 tracks. The layout of the yard is similar to a conventional retarder yard arrangement except that the distance from the hump crest to the clearance points is smaller. The absence of long conventional "clasp" retarders and the track sections for measurement of car resistance permit this distance to be reduced.

Hump height is about one half of that of a conventional yard. Gradients from crest to clearance are less steep, but beyond clearance the grade is 0.2 percent compared with about 0.1 per cent in retarder yards. Comparative profiles are shown in Fig. 1.

The Control System

Each section of track from crest to the end of the body tracks has a pre-set speed. On leaving the crest, cars first enter the acceleration section. Here cars are accelerated from 1.36 mph to 8.2 mph. This is partly achieved by gravity and partly by the hydraulic units. The next section is the switching section where the speed of 8.2 mph is maintained through the switches towards the clearance point. The deceleration section is next and here cars are retarded first to 5.5 mph, then to 3.4 mph and finally to 2.8 mph. Beyond the deceleration section a maximum speed of 2.8 mph is maintained.

The system is similar to the conventional retarder yard only in that high speeds are maintained through the switching area to increase car spacing and permit the throwing of switches. The conventional system exercises no control of car speed beyond the group retarders and relies on its ability to predict car performance from measurement of individual car resistance. The new system is able to correct car speed all the way to coupling.

At Tinsley the ability of the system to maintain a pre-determined track speed was further exploited to feed cars to the secondary hump. Cars destined for the secondary hump are kept moving at 8.3 mph along a "feed" track and on through the switching area of the second yard. Cars travel a total of 3,300 ft from the main hump to the body tracks of the secondary yard with no assistance from switch engines.

The Hydraulic Units

There are 23,500 hydraulic speed-control units in the Tinsley Yard. These are spaced along the tracks at varying intervals according to the rate of deceleration or

COMPARATIVE PROFILES FOR CLASSIFICATION YARDS
WITH CLASP RETARDERS AND DOWTY SYSTEM OF CAR SPEED CONTROL

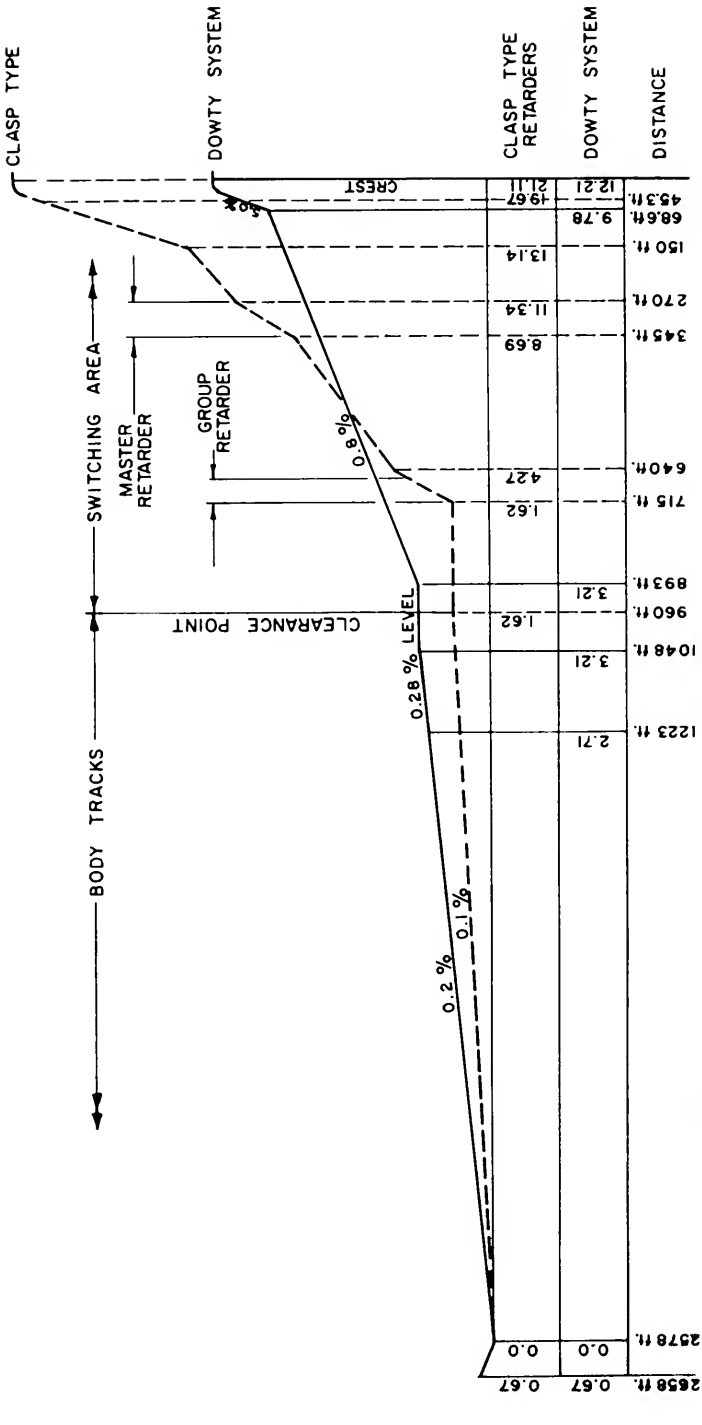
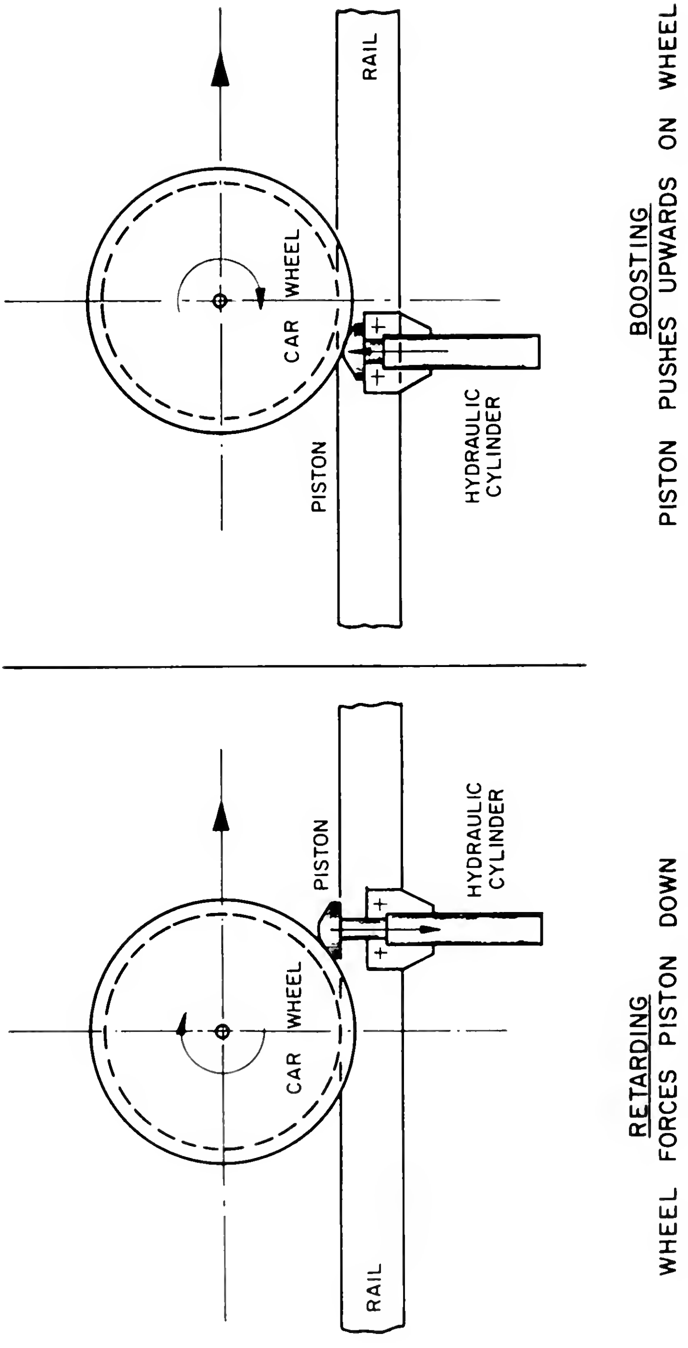
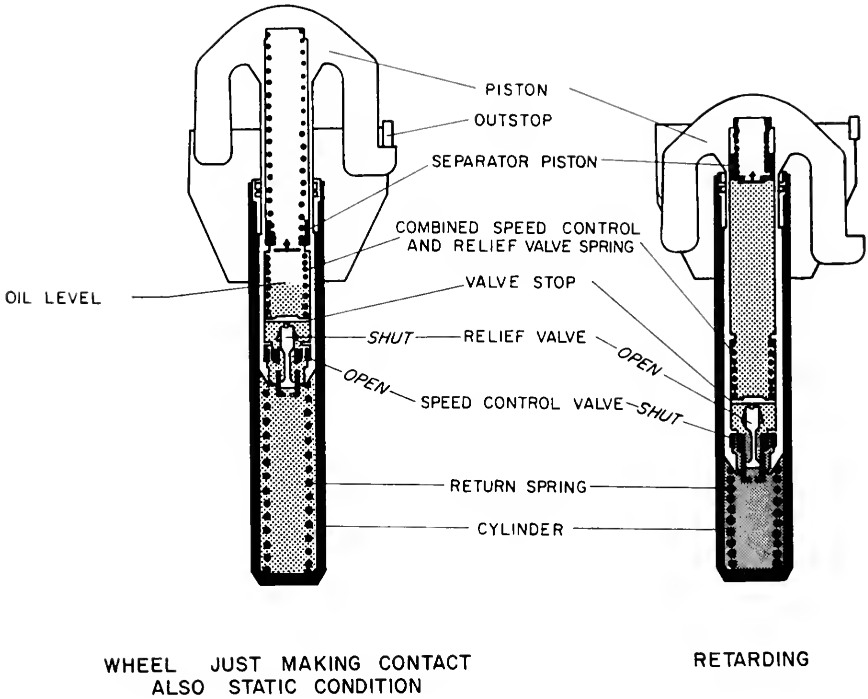


Fig. 1



UNIT ACTION

Fig. 2.



THE RETARDER

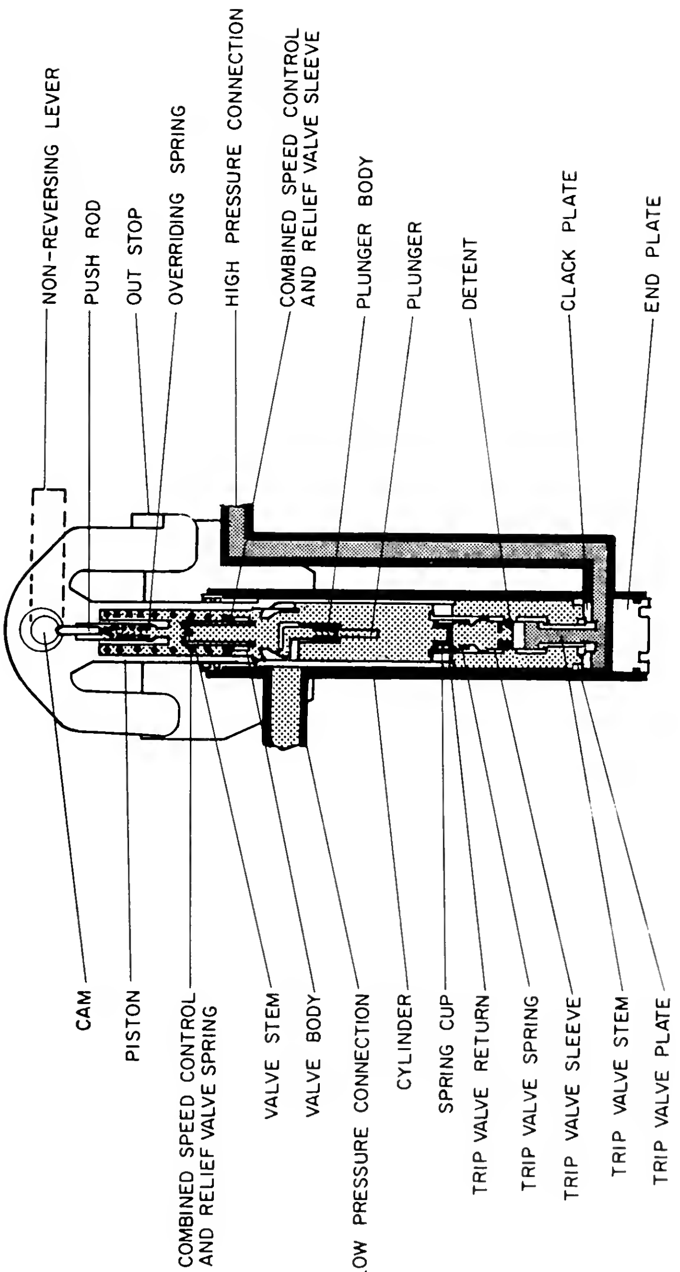
Fig. 3.

acceleration required. They are closely spaced on curved tracks where rolling resistance may be high, and widely spaced on the body tracks where speeds are low and the need for precise control is reduced.

Each unit is a small hydraulic ram bolted vertically to the inside face of the rail. The piston extends vertically above the cylinder to a height where it obstructs the passage of a flange of a car wheel. The action of a rolling car wheel in pushing the piston down affects retardation and the action of the piston pushing up on its return stroke causes acceleration. This is illustrated in Fig. 2.

There are two main types of units. One is the *Retarder Unit*—a self-contained device designed to retard the cars to a selected speed. These units do not accelerate or boost car speed. The valve arrangement is such that when a car travelling at less than the design speed depresses the piston, no resistance is encountered. At speeds above the design rate, energy is required to depress the piston and retardation is effected. Fig. 3 is a cross section of a Retarder Unit.

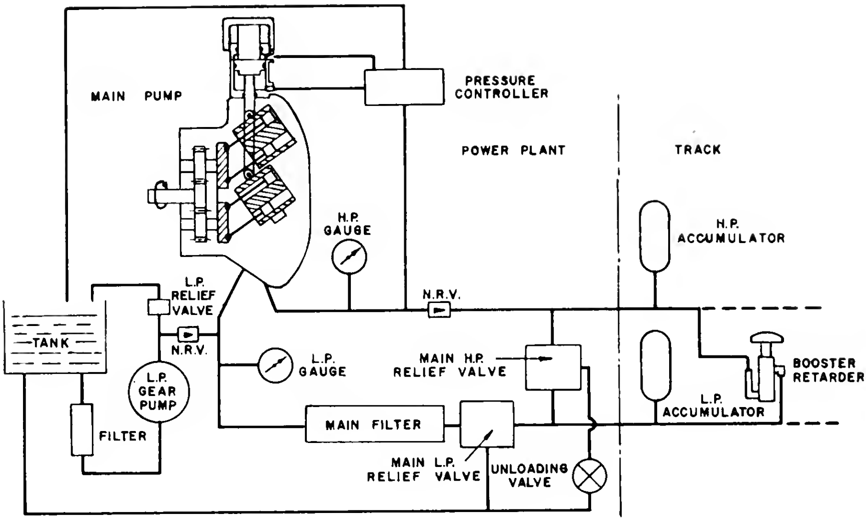
The other type is the *Booster Retarder Unit,* which is designed to retard or accelerate cars to the pre-set speed. These units are not self-contained and require high- and low-pressure oil lines from a central hydraulic power plant. Retarding action on an overspeed car is effected by the downward movement of the piston



WHEEL JUST MAKING CONTACT
ALSO STATIC CONDITION

THE BOOSTER RETARDER

Fig. 4.



LINE DIAGRAM SHOWING COMPONENTS IN POWER PLANT FOR CONTROL SYSTEM

Fig. 5.

forcing oil into the high-pressure line. The low-pressure line then restores the piston to its normal position. If the car speed is less than the design speed, oil is free to escape to the low-pressure line when the piston is depressed. At the bottom of the stroke, high-pressure oil is admitted to the cylinder and an upward thrust exerted on the return stroke. The piston engages the wheel flange and propels it towards the next unit. Fig. 4 is a cross section of a retarder-booster unit, and Fig. 5 is the power plant diagram.

Development of the System

Complete information on costs, performance, operating savings and maintenance is not available, but observations on performance after six months of operation are included as Supplement A. As Tinsley Yard is the first yard to be completely equipped with the new system, further modifications can be expected.

Some North American railroads have obtained hydraulic units for test purposes, but no reports are yet available on their effectiveness with the heavier rolling stock under more extreme climatic conditions. The original hydraulic units were designed for attachment to bull-head rail but a new style of unit to fit flat-bottom rail sections has now been developed.

SUPPLEMENT A

OBSERVATIONS ON PERFORMANCE OF TINSLEY YARD AFTER SIX MONTHS OF FULL OPERATION

The following is an extract from a report forwarded by British Railways. Metric units of measurement have been converted to their American equivalent.

Performance in Service

The Dowty system has been in full service in the new Tinsley Yard of British Railways since October 1965, and the following information is given with respect to performance to date.

The normal freight wagon on British Railways has a length of about 23 ft and a wheelbase of 9 ft 10 in. Rollability at 8 mph on straight track is assumed to vary between 0.3 and 2 percent, although there is known to be a small number outside these limits. Weight per axle may vary between 3 and 18 tons. These requirements are much more severe than those established as the comparison standard originally, with the result that unit density is higher and the humping speed is held down to 1.45 mph.

At present, wagon throughputs of 150 per hour and 3,200 per day (3 shifts, 2 locomotives) are being achieved without difficulty, although many of the trains humped are considerably shorter than the 50 wagons assumed in the capacity calculation. In the 6 months of service, not a single wagon has been damaged by collision, and no wagon content has been spilled.

A small proportion of wagons has stopped short and these have invariably been found to be faulty in some respect (axle boxes, hand brakes dropping, power brakes not effectively released). Some 30 min per day are required to push these wagons clear.

Performance of Equipment

Inevitably, the introduction of an entirely new system on such a scale has shown up weaknesses in the original design. The most prevalent has been oil leakage caused by pressure surges in the system bursting the unions of the flexible pipes. Improved design of unions and the use of accumulators to absorb the surges are curing this difficulty. The buildup of pressure from the pumps was too slow and improved regulator valves have been installed. Some units have failed to operate correctly due to sticking ball valves, and these are being modified as and when the units go in for servicing. Welding of the high-pressure connecting pipes on the booster units has proved to be unsatisfactory, and these again are being modified in the course of servicing.

Maintenance

Units. A servicing program has been established on the basis of withdrawing the 8-mph units after 500,000 axle passes. This requires about 80 units to be changed each week, and on the average about 20 are changed due to a fault having developed. All changing is done during one 8-hr shift on Sundays and, unless an oil leak is occasioned, faulty units can be left in until the weekend without affecting the yard performance. It requires about 8 to 9 min to change a booster-retarder unit and 5 min to change a retarder unit. The latter can, of course, be changed without interruption to shunting. Apart from obvious faults found during daily visual inspection, faulty units are detected by the use of a special trolley which is run for one

8-hr shift each Sunday and which can cover the yard from the hump into 10 sidings in that time. A considerable part of the switching area is therefore covered every week and the whole installation in about 8 weeks.

Pumps. There are 14 pumps in service, and one spare unit is used to enable each one to be withdrawn for inspection and service once per year. The changeover is carried out on a Sunday.

Hydraulic Fluid. There were considerable losses during the earlier months due to the leakages referred to but corrective action has steadily reduced the amount. It is, however, considered that a constant leakage of 360 U. S. gallons per week can be expected. Separators have been installed in the surface drainage system to trap-off the fluid before it reached the public system.

General Conclusions

There are no insuperable engineering problems, and it will be possible to carry out maintenance operations without intereference to the operation of the yard (assuming a minimum of 8 hr shut-down on Sundays). There has been no evidence of damage to the rails as a result of the operation of the units, and flattening of the wheel flanges noticed in the early stages has not developed to an extent to cause concern. (Proposals to lubricate the unit heads to reduce this effect have not been proceeded with.) The rate of shunting is more than adequate for the traffic now and in the foreseeable future, and the complete elimination of wagon damage is felt to have justified the higher initial cost of the system.

Report on Assignment 6

Expediting Passenger Handling in Stations and Terminals

M. K. Clark (chairman, subcommittee), M. H. Aldrich, R. O. Balsters, A. E. Biermann, W. O. Boessneck, G. H. Chabot, H. P. Clapp, W. E. Corbet, T. R. Dushel, Wm. J. Hedley, C. J. Lapinski, E. T. Lucey, L. L. Lyford, G. W. Mahn, Jr., A. Matthews, Jr., H. J. McNally, C. H. Mottier, M. B. Parker, L. J. Riekenberg, E. B. Sonnheim, S. L. Staples, C. E. Stoecker, T. DeW. Styles, Jack Sutton, J. J. Tibbits, T. W. Toal, B. H. Voor, Jr., W. E. Webster, Jr., D. W. Wessels, P. C. White.

Your committee submits, as information, the following report on expediting passenger handling in stations and terminals, with the recommendation that the subject be discontinued.

Although the subject of terminals, their design, equipment and services for handling passenger traffic, is generally described in the Manual, pages 14–2–1 to 14–2–19, incl., this report will review some of the changes which have been made recently or are being considered in railroad stations and terminals to speed the movement of passengers and to increase the efficiency of handling baggage. While passenger traffic is steadily declining on most railroads, those railroads which continue to carry passengers must provide adequate passenger handling facilities. With the advent of the high-speed lines, it is most important that tickets can be sold and collected quickly and baggage handled efficiently.

On some railroads, with a large amount of commuter business, a zone system of fares has been established. Using this system, tickets for stations within a zone are all sold at the same price, with zone prices increasing as the distance from the terminal increases. Monthly commutation tickets are of the flash type and can be checked visually.

A ticket-collection system can be established whereby gates are installed so that access to and from train platforms can be controlled. These may be manually controlled or electronically controlled by coded tickets. In the manual mode, for outbound trains, an employee is stationed at the gate and checks or collects tickets as the passengers file through. A two-way ticket booth is located by the gates for the sale of tickets during rush hours. For inbound trains, the above process is reversed. An employee stations himself at the gate and checks or collects tickets as the passengers file through. A ticket agent is on duty at the inbound gate to serve customers needing a ticket. Zoning greatly simplifies and facilitates the issuance of tickets. Gate-ticket collection, both manual and electronic, has appreciably reduced the crew requirements of local commuter trains. Loss of fares is also reduced during periods of overcrowding.

Designation of ticket windows for the sale of special tickets is also beneficial These ticket windows should be readily available to passengers and clearly marked with adequate signs to reduce loss of time of both the passengers and the ticket sellers.

To speed the movement of passengers through stations, many mechanical and related devices are used. Elevators and escalators are commonly used. In some instances a moving flat-surface rubber belt, similar to a conveyor belt, is used to carry passengers up or down a long ramp.

Various studies have been made regarding benefits to be obtained by the use of high-level platforms. It has been proven that high-level platforms will reduce station time.

Other methods of reducing station time are as follows:

(1) Using the door on one end of a car for loading passengers and the door at the opposite end for unloading passengers.
(2) Appropriate signs on platforms to direct passengers to the proper platform location for boarding designated cars, such as sleepers, parlor cars or coaches. This helps to eliminate delays by passengers walking to different platform locations before boarding a train and also reduces considerably the walking of passengers through cars.
(3) Audio and visual systems to furnish information regarding the arrival and departure of trains, track and platform location of cars, etc.

There are several methods used and under study to reduce baggage-handling problems associated with rail travel.

One method commonly used is a patron-controlled baggage cart. This method is normally used when the track and passenger concourse are at the same level. However, it can be used in multi-level stations having a gravity ramp. Using this method, individual carts are available in the station and on the train platform at strategic locations. The patron handles his own baggage on and off cart and pushes the cart to train or station and leaves it after removing his baggage.

A recent innovation is the use of patron-controlled baggage carts on powered ramps. These ramps are rubber belts with deep grooves. The patron-controlled baggage carts are equipped with grooved wheels and a holding mechanism. Existing carts can be modified for this use by changing the wheels of the baggage cart and adding six pads. The grooves on the baggage-car wheels engage in the grooves of the rubber belts and the pads thus are lowered by the height of the wheels being lowered. The pads of the holding mechanism then contact the moving belt which prevents the baggage cart from sliding on the belt. The holding power of these pads is proportionate to the load, the greater the load the greater the holding power.

Patron-controlled baggage carts can also be used with escalators; special carts are used for this movement between levels. These carts require holding ability and a self-leveling rack. Reversible escalators for up and down movement can be provided.

A monorail-type baggage conveyor can also be used. This conveyor transports baggage near ground level or overhead parallel to the patrons' path and at average walking speed. Patrons placing baggage on conveyor will remove same.

Tray elevators may also be used to move baggage from different levels. These elevators consist of hangers supported from two strands of chains which hold the trays so that they are always in a carrying position.

Another method of moving baggage from station to train is by tractor–trailer where baggage is checked by the patron near the entrance of the station. The patron obtains a receipt and the baggage is loaded on trailers designated for specific trains. The tractor moves the trailer to the designated location at the train site where the patron will claim and handle his baggage or may obtain a redcap to handle it on the train. A reverse operation is similar except that more than one point may be used at the train site to check baggage, and no sorting is necessary.

Baggage can also be moved by conveyor with manual receipt. By this method the patron checks his baggage near the main entrance to the station, obtaining a receipt, and the baggage is identified for a platform and placed on conveyor. The baggage is removed from the conveyor at a single point on the platform where the patron claims his baggage. Redcaps may be retained by the individual to carry baggage to the train or patrons may carry their own baggage.

Baggage can also be handled by using lockers on wheels. Trailers with built-in compartments are provided for each train. The patron inserts his baggage in the compartment, locks the door and retains the key. When trailer lockers are full or at a certain time before the train departs, tractors move the trailers to a designated point at the train site. On the platform, the patron using the key removes his baggage. The reverse operation works in the same manner.

Baggage can also be handled by placing it on conveyors to be moved to a dispenser. At the dispenser end of the conveyor the patron picks up his own baggage. There are several types of conveyor dispensers used, the main types being the automatic rotary dispenser and the moving diverter dispenser.

In addition to the several means indicated above to expedite the handling of passengers, it is important to provide adequate parking areas with quick ingress and egress for motor vehicle traffic where commuter traffic is involved. A report on such facilities can be found in the Proceedings, Vol. 60, 1959, pages 294 to 298, incl.

Report of Committee 9—Highways

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† Died August 27, 1967.
(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 9.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
Recommended Manual revisions will be published in Part 2 of Bulletin 610, December 1967.

2. Merits and economics of prefabricated types of highway–railway grade crossings.
Your committee is continuing its study of the various types of prefabricated highway–railway grade crossings and as pertinent information is developed it will be reported to the Association.

3. Merits of various types of highway–railway grade crossing protection, collaborating with Communication and Signal Section, AAR.
Progress report on research activities, presented as information ..... page 171

4. Investigate present requirements and practices of marking and signing private grade crossings.
Brief progress report, submitted as information .... page 174

5. Extent of use and effectiveness of highway-type stop signs at highway-railway grade crossings.
Brief progress report, submitted as information .... page 176

6. Air rights for highways over railroad property.
   This is a new assignment, and your committee has begun to gather information on the various aspects of this use of railroad property. As pertinent information is developed it will be reported to the Association.
7. Conduct study with the view toward developing alternate types of automatic crossing protection, collaborating with Communication and Signal Section, AAR.
   Progress report, submitted as information .... page 177

THE COMMITTEE ON HIGHWAYS,
R. DEJAIFFE, *Chairman.*

AREA Bulletin 609, November 1967.

Victor Roy Walling
1880-1967

Victor Roy Walling, retired chief engineer, Chicago & Western Indiana Railroad and Belt Railway of Chicago, passed away on August 27, 1967. He is survived by a son, William N. and a grandson also named William, of Coral Gables, Fla.

Mr. Walling was born May 24, 1880, at Tripoli, Iowa, graduated from Kansas University in 1901 with B. S. degree and received honorary C. E. degree in 1911. His career in railroading commenced as draftsman in June 1901, with the Cananea Consolidated Copper Company at Cananea, Mexico; later he served as instrumentman with the Southern Pacific from January 15, 1903 to March 1, 1907, when he returned to the Cananea Consolidated as first assistant engineer, then superintendent and chief engineer of this company from August 12, 1907, to June 20, 1912. On the latter date he joined the Chicago & Western Indiana Railroad, serving this road and the Belt Railway successively as first assistant engineer, principal assistant engineer, engineer maintenance of way, superintendent, and assistant chief engineer, becoming chief engineer of both roads on October 1, 1948. He retired from railway service on June 30, 1952.

He joined the AREA in 1909 and became a Life Member in 1944. Continuously since 1931 he was a member of Committee 9—Highways, having been elected Member Emeritus on September 25, 1955. He was a member of Committee 11—Engineering and Valuation Records, from 1921 to 1929, Committee 14—Yards and Terminals, from 1941 to 1948, and for three years following retirement in 1952 was a member of Committee 25—Waterways and Harbors. In addition to the AREA, Mr. Walling also was a member of ASCE, American Association of Railroad Superintendents, Maintenance of Way Club (Chicago), Roadmasters and Maintenance of Way Association and Western Society of Engineers.

A legion of friends in the railroad world, the Association, and fellow members of Committee 9, especially, will miss him.

Report on Assignment 3

Merits of Various Types of Highway–Railway Grade Crossing Protection

Collaborating with Communication and Signal Section, AAR

R. W. Mauer (chairman, subcommittee), H. L. Michael (vice chairman, subcommittee), F. N. Barker, G. B. Blatt, W. B. Calder, L. T. Cerny, C. A. Christensen, F. R. Cummings, F. C. Cunningham, V. G. Donlin, C. I. Hartsell, Wm. J. Hedley, C. L. Holman, J. A. Holmes, H. A. Hunt, R. V. Loftus, E. S. Miller, J. E| Reynolds, P. H. Slack, R. E. Skinner, J. E. Spangler, C. H. Stephenson, W. S. Titlow, H. J. Wilkins, G. A. Williams, H. L. Woltman, K. E. Wyckoff.

Within the last two years several significant research projects have been completed in the area of highway–railway grade crossing protection. This report provides a brief statement about four of these studies and bibliographic information on each. Abstracts covering the final reports of these four studies are also included as Appendices.

Bibliographic Information

1. "Factors Influencing Safety at Highway–Rail Grade Crossings", Alan M. Voorhees and Associates, Inc., NCHRP Report 49, Highway Research Board, National Academy of Sciences, Washington, D. C. (in publication, completion expected early in 1968).
2. "Evaluation of Safety at Railroad–Highway Grade Crossings", Thomas G. Schultz, Ph.D. Thesis, Purdue University, Lafayette, Ind., August 1965.
3. "Evaluation of Safety at Railroad–Highway Grade Crossings in Urban Areas", William D. Berg, MSCE Thesis, Purdue University, Lafayette, Ind., January 1967.
4. "Optimum Hazard Formula for Railroad Crossing Protection for Lincoln, Neb.", Georgy Bezkorovainy and Robert G. Holsinger, Traffic Engineering Department, Lincoln, Neb., February 1967.

Comments

The most comprehensive and significant of these research studies is the one performed by Alan M. Voorhees and Associates, Inc., under contract for the National Cooperative Highway Research Program. This Program is administered by the Highway Research Board, National Academy of Sciences, Washington, D. C., with funds made available by the various state highway departments through the American Association of State Highway Officials in cooperation with the Bureau of Public Roads. Information for the study was obtained from many sources, including 16 state highway departments, 5 cities, 5 counties, the Interstate Commerce Commission and the Pennsylvania Railroad. The report will be available for purchase in early 1968.

The two research studies by the Joint Highway Research Project are, respectively, for rural and urban areas. The data used were for the State of Indiana and the research was financed by the Indiana State Highway Commission. In addition to findings of factors which affected accident hazard at crossings in Indiana, two nomographs, one for urban and one for rural, were prepared for quick determination of the relative hazard index of railroad–highway grade crossings for priority determination of protection improvement.

The Lincoln, Neb., study is an evaluation for conditions in that city of the applicability of 11 hazard index formulas. The optimum formula of these 11 was desired.

Additional information on each of these studies is given in the abstracts accompanying this report.

One recently announced program of the Department of Transportation is likely to produce further significant activity in the railway–highway grade crossing area. The Secretary of Transportation has directed that each state highway department select one grade crossing for each 4,000 miles of its Federal-Aid highway system for testing of the "most suitable known or proposed system of protection." The knowledge obtained as a result of this special effort on about 200 crossings in the nation should improve the design and development of protective devices for general use.

Considerable activity in the railway–highway grade crossing protection area will undoubtedly occur in the immediate and near future. Your committee plans to maintain close association with this activity and hopes to continue evaluation of it. Your committee recommends continuation of the assignment.

APPENDIX I—FACTORS INFLUENCING SAFETY AT HIGHWAY–RAIL GRADE CROSSINGS

By ALAN M. VOORHEES & ASSOCIATES, INC.
Prepared for National Academy of Sciences, Highway Research Board

ABSTRACT

The broad objective of this study was to interpret available information for immediate and practical application to the problem of improving safety at highway–railway grade crossings. Available information was generally one of three types:

1. Data on physical features at crossings related to the number of accidents which had occurred there.
2. Original reports on individual accidents, and data taken from the reports and punched on cards.
3. Previous research.

The report represents a comprehensive analysis and review of this information.

A probability model was developed for forecasting the probability of accident occurrence at crossings. The model allows the separate prediction of expected accidents which involve trains and accidents which do not involve trains but occur at the crossing.

It was found that train accident occurrence is related to the probability of vehicle and train arrivals and type of protection at the crossing. Other related factors are the environment of the crossing (i.e., whether it lies in a developed or an undeveloped area), the angle of crossing, the approach gradient and number of highway lanes.

Non-train-involved accidents are related to the number of highway vehicles. Other factors are the presence of automatic gates and the number of trains.

Accidents which involve trains were found to account for only about 20 to 30 percent of the accidents which occur at railroad crossings.

Warrants for improvements at railroad crossings were developed. They are based upon the cost of improvements and the anticipated savings in accidents. A method of assigning priority to a group of crossings which warrant improvement is proposed. This method considers the rate of return on the investment.

An extensive review of human factors literature led to the development of general principles for improving warning to the motorist. Alternative signs were designed based upon these principles and the analysis of available data. From the alternatives, specific signs were selected and are recommended for installation at railroad crossings.

It was found that drivers travelling at prevailing highway speeds generally are not provided with adequate sight distance during their approach to crossings to enable them to evade approaching trains through normal braking or accelerating. A method for determining the adequacy of sight distance at railroad crossings is proposed. The method incorporates normal highway design criteria and train speed.

Recommendations are made concerning future research which would be of value in developing criteria for improving safety at highway–rail grade crossings.

Other results of this study include a review of previous research related to railroad crossings and a review of human factors literature applicable to the design of warning devices.

APPENDIX II—EVALUATION OF SAFETY AT RAILROAD–HIGHWAY GRADE CROSSINGS

By WILLIAM D. BERG, THOMAS G. SCHULTZ, and J. C. OPPENLANDER
Joint Highway Research Project, Purdue University

ABSTRACT

The purpose of this research investigation was to determine the relative effects of those factors which significantly influence the accident patterns at railroad–highway grade crossings; to develop mathematical models that measure the relative safety or hazard of grade crossings; and to establish a priority rating system, based on the models, for determining protection improvements.

The mathematical techniques of regression analysis and discriminant analysis were utilized to develop models for predicting the relative hazard at railroad–highway grade crossings. The models were functionally related to factors and variables which were descriptive of environment, topography, geometry of the crossing, and rail and highway traffic patterns.

For rural grade crossings, a regression model was formulated to express relative hazard as a function of average daily highway traffic, average daily train traffic, roadside distractions, pavement width, and number of tracks. Warrants based on current levels of protection in Indiana were developed for selecting the recommended type of protective device at rural grade crossings.

For urban grade crossings, a discriminant model with linearly assigned probabilities expressed potential hazard as a function of protective device, average daily highway traffic, average daily train traffic, degree of effective sight distance, and roadside distractions. A methodology was developed for selecting a minimum of grade crossing protection and establishing priorities for the improvement of protection at urban railroad–highway grade crossings.

APPENDIX III—OPTIMUM HAZARD INDEX FORMULA FOR RAILROAD CROSSING PROTECTION FOR LINCOLN, NEB.

By GEORGY BEZKOROVAINY and ROBERT G. HOLSINGER
Traffic Engineering Department, Lincoln, Nebraska

ABSTRACT

Lincoln's 180 at-grade railroad crossings were evaluated by 11 well known hazard index or accident probability formulas. Some of the tested formulas have been obtained through statistical analysis while in others the various factors have been arbitrarily selected. Some formulas are easy to compute and require very little data, while others require detailed data and entail tedious computations.

A Spearman's r_s statistical analysis was used to test whether there was correlation among the ranks arrived at from the use of various formulas. For the purpose of this analysis, the crossings were tested in three groups: signalized crossings, unsignalized crossings and all railroad crossings.

The results of the correlation analysis show that all 11 formulas are associated when the "unsignalized" group and the "all" group are subjected to Spearman's r_s analysis. The results of the "signalized" group analysis show that most of the 11 formulas are associated. However, the cases of non-association are due to the fact that some formulas reduce the hazard index values for existing automatic protection devices, while other formulas do not.

Since all 11 formulas are associated, the method which best represents the composite of all formulas could be regarded as the formula which best serves the need of the City of Lincoln. The New Hampshire formula was found to be the optimum formula:

$$H.I. = VTP$$

where $H.I.$ = hazard index
V = average 24-hr traffic volume
T = average 24-hr train volume
P = protection factor (gates = 0.1; flashing lights = 0.6; sign only = 1.0)

Report on Assignment 4

Investigate Present Requirements and Practices of Marking and Signing Private Grade Crossings

H. W. Walbright (chairman, subcommittee), H. J. Barnes, W. A. Buckmaster, C. A. Christensen, F. C. Cunningham, F. Daugherty, V. C. Donlin, C. H. Gaut, C. L. Holman, J. A. Holmes, R. F. MacDonald, R. W. Mauer, C. B. May, H. L. Michael, E. S. Miller, D. J. Moody, R. E. Skinner, R. F. Spars, C. W. Traister, H. J. Wilkins, H. L. Woltman.

No new legislative action or public utility commission order dealing with this subject has been reported to this subcommittee other than in California, one of the four states previously reported on in Bulletin 602, November 1966, page 149.

In California, the Public Utilities Commission authorized the issuance of a report by an examiner which recommended that each private crossing at grade should be protected by a minimum of one standard crossbuck sign, supplemented with a standard No. 9 private crossing sign mounted at a minimum height of 5 ft above ground level. The specifications for the standard No. 9 private crossing sign call for a sign 18 in by 12 in. in size, with the words "private crossing" in white letters 4 in. in height with a stroke of ½ in on a black background, with the letters reflectorized.

The California Legislature passed Bill AB 1776, signed into law by the Governor on July 27, 1967, which provides for the placement of octagonal stop signs and such other signs as the Commission may recommend at private and farm crossings. The specific language of this new Code Section 7538 reads as follows:

"At any farm or private grade crossing of a railroad where no automatic grade crossing protective device is in place the commission shall be empowered to prescribe, as a means of protecting the crossing, one or more stop signs of the type described in Section 21400 of the Vehicle Code or of such other design as it may consider appropriate. At any grade crossing where stop signs are installed or in place, before traversing such crossing the driver of any vehicle shall stop such vehicle not less than 10 nor more than 50 feet from the nearest rail of the track and while so stopped shall listen, and look in both directions along the track, for any approaching train or other equipment using such rails. The vehicle shall remain standing while any train or other equipment using such rails is approaching the crossing and is close enough to constitute a hazard. A driver of any vehicle who fails to keep his vehicle standing while any train or equipment using such rails is approaching the crossing and which is so close as to constitute a hazard is guilty of a misdemeanor."

The type and shape of signs to be used is still a major issue in the case as far as the California railroads are concerned, and at least one major railroad in that state has filed an exception to the Commission examiner's report and has suggested as an alternate the use of a 24-in-square reflectorized red and silver stop sign with the words "Private R.R. Crossing" superimposed on the sign, reading vertically from top to bottom. A separate "No Trespassing" sign to be attached below the stop sign is also proposed. If the standard boulevard stop sign is used it is then advocated that a private crossing and no trespassing combination sign be used below the octagonal stop sign.

The provision of the examiner's report recommending a Commission Order to require every railroad in the State, within three years from the effective date of the Order, to furnish the Commission an inventory of all private crossings at grade, has not been subsequently acted on by either the Commission or the California Legislature to the best knowledge of this committee.

This is a progress report, submitted as information, with the recommendation that the subject be continued.

Report on Assignment 5

Extent of Use and Effectiveness of Highway-Type Stop Signs at Highway-Railway Crossings

K. E. Wyckoff (chairman, subcommittee), H. J. Barnes, W. G. Calder, R. L. Charlow, F. R. Cummings, F. C. Cunningham, F. Daugherty, V. G. Donlin, W. E. Free, C. I. Hartsell, Wm. J. Hedley, R. F. MacDonald, R. W. Mauer, C. B. May, H. L. Michael, E. S. Miller, D. J. Moody, R. E. Skinner, P. H. Slack, J. E. Spangler, R. F. Spars, H. J. Wilkins, G. A. Williams, H. L. Woltman.

Oconomowoc, Wis.

In Bulletin 602, November 1966, a progress report was presented giving particulars of the supplemental stop sign installations at seven highway–railway grade crossings at Oconomowoc, Wis. An important part of this report was the observations made with respect to the motorists' observance of the stop requirement.

In May of this year another inspection was made by members of this subcommittee. Combined results of the 1966 and 1967 surveys are as follows:

How Motorists Observed Stop Signs, Expressed As A Percent

	Autos	*Trucks*	*Buses*	*All Vehicles*
Complete stop	72.92	70.40	93.33	72.67
Moving, less than 5 mph*	23.73	26.00	6.67	23.96
Moving, about 10 mph*	2.72	2.85	0.00	2.73
Moving, about 20–25 mph*	0.63	0.75	0.00	0.64

* Estimated

The above percentages represent 4,069 motorists during 16 hours of observation. There was about a 9 percent decrease, 78.35 percent in 1966 versus 69.61 percent in 1967, of those drivers that came to a complete stop at the stop sign before proceeding across the railroad tracks. The percentage of drivers that stopped completely or were in the 0- to 5-mph range was 96.50 for 1966 and 96.71 in 1967. Even though the 0-5 mph drivers did not completely stop, they were apparently aware of the stop requirement.

Some general observations made during the surveys were:

1. Most motorists look before crossing the tracks, but not necessarily in both directions.
2. Some of the approaches are relatively steep (10 percent) and this could be a factor why drivers are not coming to a complete stop.
3. During the 1967 survey it was noted that one of the 26 motorists that failed to stop (20–25 mph range) was an out-of-state registered vehicle.

This is a progress report, submitted as information with the recommendation that the subject be continued.

Report on Assignment 7

Conduct Study with the View Toward Developing Alternate Types of Automatic Crossing Protection

Collaborating with Communication and Signal Section, AAR

C. I. Hartsell (chairman, subcommittee), F. N. Barker, H. J. Barnes, G. B. Blatt, W. A. Buckmaster, W. B. Calder, R. L. Charlow, F. R. Cummings, T. P. Cunningham, V. G. Donlin, Wm. J. Hedley, H. A. Hunt, R. V. Loftus, R. F. MacDonald, H. L. Michael, J. E. Reynolds, P. H. Slack, J. E. Spangler, R. F. Spars, C. W. Traister, H. L. Woltman.

Of interest to the Association is an experiment being conducted in the State of Missouri with the avowed purpose of "improved crossing protection at highway–railway grade crossings without flashing lights."

During the year 1967, and at the order of the Missouri Public Service Commission, four railroads have each made an installation of these "Electric Railroad Crossing Signals." The signals are standard 90-deg railroad crossing signs with a continuously blinking 12-in-diameter yellow beacon above and below each crossbuck.

The Missouri State Highway Commission bore a flat $250 share of the cost per pair of signals, with the railroads bearing the remaining installation cost and the entire cost of operation and maintenance.

This is a progress report, submitted as information, with the recommendation that the subject be continued.

Report of Committee 20—Contract Forms

°J. T. Evans, *Chairman*

°E. A. Graham, *Vice Chairman*
°W. F. Burt, *Secretary*
°C. W. Colborg
°C. G. Nelson
°J. D. Taylor
°E. M. Hastings, Jr.
°N. L. Grider
J. C. Britt
J. F. Bruckner, Jr.
J. K. Christensen
R. F. Correll
A. B. Costic
A. P. Fish
P. J. Freeman
R. C. Heckel
R. P. Hoffman
R. W. Humphreys
F. M. Jones
J. S. Lillie (E)
D. F. Lyons
R. M. Mason
W. G. Nusz (E)
G. W. Patterson (E)
J. L. Perrier
J. W. Rach
W. B. Small
C. W. Smith
J. L. Southard
D. R. Stewart
W. R. Swatosh (E)
W. B. Tittsworth, Jr.
J. W. Wallenius
H. L. Zouck
Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 20.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
Progress report, presented as information .... page 180
2. Form of agreement to cover experimental demonstration of equipment and materials on railway property.
Final report, with form of agreement submitted for adoption and publication in the Manual, will be published in Part 2 of Bulletin 610, December 1967.
3. Form of agreement for handling truck trailers and containers at terminals.
Final report, with form of agreement submitted for adoption and publication in the Manual, will be published in Part 2 of Bulletin 610, December 1967.
4. Form of blanket agreement covering utility crossings.
Final report, with form of agreement submitted for adoption and publication in the Manual, will be published in Part 2 of Bulletin 610, December 1967.
7. Bibliography on subjects pertaining to contract forms.
Progress report, presented as information .... page 180

The Committee on Contract Forms,
J. T. Evans, *Chairman*.

AREA Bulletin 609, November 1967.

Report on Assignment 1

Revision of Manual

C. W. Colborg (chairman, subcommittee), W. F. Burt, J. K. Christensen, R. F. Correll, E. A. Graham, P. J. Freeman, E. M. Hastings, Jr., D. F. Lyons, J. L. Perrier, W. B. Small, J. A. Taylor, W. B. Tittsworth, Jr., J. W. Wallenius, H. L. Zouck.

The subcommittee has prepared a preliminary report on this assignment which was reviewed and discussed by the committee as a whole. Further reports will be circulated among the membership of the entire committee for their comments and criticisms.

The work will be continued.

Report on Assignment 7

Bibliography on Subjects Pertaining to Contract Forms

N. L. Grider (chairman, subcommittee), W. F. Burt, E. A. Graham, J. C. Britt, A. B. Costic, R. C. Heckel, J. W. Rach, W. B. Small, J. L. Southard.

Your committee submits the following annotated bibliography as information:

1. *Modern Railroads,* February, 1967, case history of a "Total Transportation and Distribution" concept applied successfully to the harvesting, processing, and transportation of California's "Diamond" walnuts, through the use of contract truck-substituted service.

2. *Modern Railroads,* January, 1967, "Highlights of the News" article sub-titled "Railroads, car leasing firms offer new ideas", deals with the concept of leasing equipment to two or more companies with nonconflicting seasonal needs for greater car utilization.

3. *L&N Magazine,* January, 1965, article by Barbara Bess titled "Customized Contract Service" concerning centralized processing of all contracts on the L&N Railroad by use of IBM Programmed Magnetic-Tape "Selectric" typewriter.

4. "Before You Sign That Contract", R. Gottlieb, in *Motor Trends,* 19:52–4, June, 1967.

Report of Committee 13—Environmental Engineering

°J. J. Dwyer, *Chairman*

°C. F. Muelder, *Vice Chairman*
°H. E. Graham, *Secretary*
°**P. M. Miller**
°**J. C. Roberts**
°**R. N. Johnson**
°**T. L. Hendrix**
°**J. L. Goss**
°**C. E. DeGeer**
°**J. W. Zwick**
R. C. Archambeault
W. F. Arksey
R. A. Bardwell
V. C. Barth
J. M. Bates
R. S. Bryan, Jr.
L. R. Burdge
D. E. Drake
A. E. Dulik
P. P. Dunavent, Jr.
J. L. Engler
T. I. Gray
W. C. Harsh
R. R. Holmes
F. O. Klemstine
A. J. Levene
H. L. McMullen (E)
E. T. Myers
M. F. Obrecht
Henry Parrish, Jr.
A. B. Pierce (E)
W. D. Phelps, Jr.
J. M. Ryan
M. W. Sibley
W. A. Tennill
T. A. Tennyson
H. W. Van Hovenberg (E)
C. B. Voitelle
E. M. Walters
J. E. Wiggins, Jr.
Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 13.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Chapter 13 was reviewed in detail last year and brought up to date with revisions where necessary. The only revision needed this year is the change in committee name, on the pink introductory page and on the Table of Contents page i, from "Water, Oil and Sanitation Services" to "Environmental Engineering," which became effective August 4, 1967, as outlined in AREA News for September–October 1967.
2. Corrosion control—engine cooling systems.
   Progress report, presented as information .... page 182
3. Design, construction and operation of railroad sanitary and servicing facilities, and relations with governmental agencies pertaining to these facilities.
   Activity in this area has been carefully monitored during the last 12 months, but happenings have been of insufficient importance to constitute a report this year.
4. Air pollution abatement.
   Progress report, presented as information .... page 185
5. Small sewage disposal systems.
   Progress report, presented as information .... page 186

6. Railway waste disposal.
   Progress report, presented as information .... page 187
7. Cleaning, sterilizing and handling drinking water containers.
   Progress report, presented as information .... page 189
8. Disposal or reuse of chromate-treated cooling water.
   The initial report on this subject appeared in Bulletin 602 for November 1966 as information. Conditions beyond the control of the committee, including loss of the subcommittee chairman, prevented completion of a report this year.
9. Protective coatings for buried pipe.
   Progress report, presented as information .... page 190

THE COMMITTEE ON ENVIRONMENTAL ENGINEERING,
J. J. DWYER, *Chairman*.

AREA Bulletin 609, November 1967.

Herbert Eugene Silcox
1886-1967

Herbert Eugene Silcox, retired assistant engineer water supply, Chesapeake & Ohio Railway, died at Richmond, Va., August 8, 1967. He is survived by his widow, Ruth McKay Silcox; a daughter, Dorothy Silcox; and a son, Howard R. Silcox.

Mr. Silcox was born October 12, 1886, in Rockville, Conn., and received his technical education at Michigan Agricultural College (now Michigan State University).

He entered railroad service in 1909 on the Missouri Pacific, where he advanced from rodman to division engineer. He joined the C&O in 1924 as assistant engineer water supply, which position he held until his retirement on October 31, 1951.

Mr. Silcox was active in the American Railway Engineering Association, of which he became a member in 1920. He served with distinction on Committee 13, being vice chairman in 1948 and chairman 1949–1951. He was made a Life Member of the AREA in 1952, and was elected Member Emeritus of Committee 13 in 1956.

Report on Assignment 2

Corrosion Control—Engine Cooling Systems

P. M. MILLER (chairman, subcommittee), W. F. ARKSEY, R. A. BARDWELL, W. C. HARSH, M. W. SIBLEY, C. B. VOITELLE, E. M. WALTERS.

While there are several types of corrosion that may be encountered in environments similar to that of a typical diesel locomotive cooling system, the scope of this report is concerned with limiting corrosion due to water conditions and its prevention by proper use and control of inhibitors.

Water used for fill or makeup to diesel locomotive cooling systems should be either naturally or artificially made free from materials which could deposit mud, sludge, scale, or cause corrosion in such systems, or be harmful to any of the materials of construction of such cooling systems.

Naturally soft water; distilled, deionized, or zeolite-softened water, or condensate are, with proper inhibitors, suitable for fill or makeup purposes. Experience has shown that the following limits should be adhered to for finished makeup water, exclusive of inhibitors:

Chloride	40 ppm maximum
Sulfate	100 ppm "
Total hardness	120 ppm "
Total dissolved solids	340 ppm "
Suspended solids	17 ppm "
Oil	0 ppm "
pH value	6 minimum

Raw waters falling within these limits may be used as makeup water generally without further treatment except for inhibitors. Natural waters exceeding the foregoing limits will need treatment or processing in order to bring them within the recommended limits.

There are two systems of inhibitors in general use. One is based on soluble hexavalent chromates, and is generally acknowledged to be the most effective. The other is based on a boron-nitrogen system, usually in the form of borate and nitrite. Either system will provide adequate protection of the cooling system provided that sufficient concentration of inhibitor is present at all times and the cooling system is reasonably well maintained.

Both systems have advantages and disadvantages. The chromate is very effective. The yellow color makes water leaks easy to spot; simple chemical tests for chromate concentration are available and can be practically applied on a routine basis. Conversely, chromates present a disposal problem because of restrictions on the dumping of hexavalent chromium compounds into natural water or sewers. Chemical conversion and disposal of chromate is complicated. Dry chromate compounds may present a handling problem, particularly where use of a bulk compound is involved. Chromates are not compatable with glycol-type antifreezes.

The borate-nitrite systems requires a higher concentration of material to be effective, does not show up water leaks unless a dye is added, and chemical titration control tests may be more difficult to apply on a routine basis. This last drawback may be offset, however, by using conductivity testing as a means for controlling concentration, as it is simple and reliable. Although the primary reason for using borate-nitrite treatment stems from the disadvantages of the chromates, some authorities are now limiting the permitted disposal of this non-chromate-type treatment. At present these limitations have been imposed on some areas where citrus fruits are grown, due to reported ill effects upon such crops. One important advantage of the borate-nitrite compounds is that they are compatable with glycol antifreeze, whereas chromates are not. Further, handling problems associated with chromates are generally greatly reduced when a borate-nitrite material is used.

Regardless of which system is used, it is mandatory to maintain a minimum inhibitor concentration in cooling sytems in order to prevent the occurrence of corrosion associated with water. Control tests must be run regularly at sufficient intervals to insure that makeup inhibitors are added to the cooling system often enough to maintain the minimum required concentration. It goes without saying that the cooling systems should be maintained in as leak-free a condition as possible, because leaks require make-up, which in turn requires more frequent addition of inhibitors. On the other hand, with a tight cooling system, testing at two- to four-week intervals may be sufficient to maintain the minimum required.

It should be noted that makeup consisting of condensate, or distilled or demineralized waters, may be quite corrosive if inhibitor is not added together with the makeup. Well or other water exceeding recommended maximums for sludge and scale-forming materials should never be added to a cooling system except in emergency, since with the high heat transfer rates required in modern diesel power, any reduction in thermal transfer efficiency is a potential cause of serious trouble in areas depending on adequate removal of heat for proper operation.

Testing

There are a variety of test methods available for checking the concentration of either inhibitor system. These tests range from conductivity measurements to chemical tests for the amount of chemical involved. Most chemical companies furnishing inhibitor compounds also furnish test kits and detailed instructions on the operation thereof, which should present no problem in the standard railroad running repair shop or enginehouse.

Summary

Proper control of potentially corrosive conditions which may occur in the cooling systems of diesel locomotives may be minimized by:

1. Proper selection or treatment of makeup water to insure compliance with the standard limits of impurities previously set forth.
2. Use of a properly compounded inhibitor which is designed to interfere with the mechanism of corrosion found in cooling system environments to the point of complete inhibition thereof, providing minimum recommended concentrations are maintained.
3. Adequate test programs with checking done often enough to ensure that the locomotive builders' minimum recommended concentration of inhibitor is maintained at all times.
4. Proper maintenance of the cooling systems, keeping leaks to a minimum.
5. Setting up a system of treating plants and facilities to insure that all makeup to cooling systems is a properly conditioned water, adequately protected with approved inhibitors, and under a reasonable degree of control.

This report is presented as information.

Report on Assignment 4

Air Pollution Abatement

R. N. Johnson (chairman, subcommittee), R. C. Archambeault, J. M. Bates, D. E. Drake, A. E. Dulik, J. L. Goss, W. C. Harsh, E. T. Myers, W. D. Phelps, Jr., C. B. Voitelle.

The objective of your committee on Air Pollution Abatement is to establish criteria, based on local, state and national requirements, to assist in the development of uniform standards for comparable railroad operations performed at various locations on intrastate systems or throughout the railroad industy.

With the advent of the national "Clean Air Act" of 1965, support and encouragement were provided to increase public awareness of the present and potential hazards from air contamination and the needs for pollution controls. These efforts have produced a wide range of standards and requirements proposed by local or state agencies to meet the diversity of conditions encountered. Information which has been obtained on the various regulations in effect at this time is not sufficient to permit a detailed analysis or summary of specific requirements or standards. However, the following items included in a typical set of regulations indicates the general considerations for contamination control and the approach to development of control standards:

Industrial emissions—smoke, fumes, gases, and dust from power plants, shops, and processing facilities:

1. Intensity of discharge from any source equal or greater than No. 2 Ringleman smoke density is limited to 3 min in any 1-hr period.
2. Quantity of particulate matter is limited in proportion to the amount of material processed by the following ratio: Maximum emission in pounds per hour, $E = 55 \times P^{0.11} - 40$, where P is the tons per hour of material processed.
3. Specific contaminants—emission of sulfur dioxide is restricted to 2000 ppm maximum at ground level; 1.0 ppm for 20 min of any 1 hr, and 0.1 ppm average over any 8-hr period.

Vapors from petroleum products—storage and handling:

1. Volatile liquids and gases having a vapor pressure of 1.5 or more require storage facilities which will prevent any escape of vapors.
2. Handling facilities for gasoline in quantities over 20,000 gal per day are required to have provisions to collect or control the emission of vapors.
3. Oil separation from waste water containing more than 200 gal of petroleum products equal or more volatile than kerosene are required to be handled to prevent the possible escape of vapors into the atmosphere.
4. Solvent evaporation from cleaning and finishing materials is limited for specific types of materials.

Combustile waste burning:

1. Open burning is prohibited in any and all forms except for safety flares, recreational purposes or where special permission is obtained.

2. Incineration of waste materials requires approval of both equipment and procedures for all applications.

Combustion engine exhausts are excluded from the typical regulation for general air pollution as mobile equipment or moving sources of contamination.

General requirements of the regulations specify technical details of sampling, testing, control procedures and operations of facilities. Approvals of designated authorities are required for virtually all phases of planning, design and operation of any new facilities involving potential air contamination.

With the current interest and government support of efforts to regulate air pollution for the wide variation of conditions and needs, it is anticipated that the activities of this committee will be increased to provide a basis for adequate control of contamination from railroad operations. The success of the committee's work will depend upon representation and information from railroads operating in areas where variations of conditions and requirements for air pollution control are prevalent. Your interest and contributions to this effort are solicited.

This report is presented as information.

Report on Assignment 5

Small Sewage Disposal Systems

T. L. Hendrix (chairman, subcommittee), V. C. Barth, G. J. Chappell, W. C. Harsh, P. M. Miller, H. Parrish, Jr., J. M. Ryan, J. E. Wiggins, Jr., J. W. Zwick.

Recommended practices for railway sewage disposal systems are generally covered in Part 8, Chapter 13 of the Manual, under the title, "Railway Sewage Disposal Facilities." Design details for septic tank systems and Imhoff tanks are included.

This report is intended to elaborate on the package-type sewage treatment system mentioned under Sec. H of the above mentioned document and to give information on some design criteria for lagoons under Sec. I thereof.

Anaerobic Digestion

Systems using this principle are generally known as mechanical Imhoff tanks because the settleable solids drop into a lower chamber where digestion takes place. However, a recirculating pump, operating on a timed cycle, is usually provided to discharge into the gas vent to break up scum and reduce the maintenance required.

In some cases, where a higher degree of treatment is necessary than is obtained from anaerobic digestion, a secondary treatment must be provided. This may consist of a trickling filter where the primary effluent is sprinkled on a bed of rocks, or an aerobic process similar to that described below.

Aerobic Digestion

These systems depend upon bubbling sufficient air through the sewage to support bacteria which reduce the sewage solids to an innocuous sludge. Some units are blowers and porous diffusion plates. Others introduce air by the cavitation effect of rapidly rotating propellers. All aerobic systems require continuous operation of motors to supply the air.

Some states allow the effluent from aerobic systems to be discharged directly to streams, while others require sludge separation.

Post Chlorination

Most states require the effluent from a sewage treatment plant to be chlorinated to kill remaining bacteria. Chlorine dosage is dependent on the chlorine demand of the effluent, and a small residual of about 0.1 ppm must be maintained. A 20-min retention in the chlorine contact tank is usual.

Chlorination may be accomplished by chlorine gas or by hypochlorites, but in any but the smallest units, gas is usually the more economical. As most sewage plants will require lift stations, the chlorinator can be hooked up to operate when the lift pumps do, which makes control simple.

Segregation

Segregation of domestic sewage from storm drainage is highly desirable in order to keep the capacity of the treating plant within economical size. If mixed sewage must be handled, a diversion manhole can be used to direct normal flows through the treatment plant and arranged to automatically by-pass heavy storm drainage. The size of the diversion will depend upon approval of the local health agency having jurisdiction.

Lagoons

This is a relatively new approach to sewage treatment, and is probably the most economical method available if terrain conditions are favorable. There is wide variation among the design criteria of the various states. Lagoons generally provide 1 acre of water surface for each 100 to 400 people served, or for each 20 to 70 lb of BOD per day. Usual depths are 3 to 5 ft. Chlorination or other post treatment is not required by most states, but adequate fencing to prevent accidental trespass by children or animals is necessary.

Although well designed lagoons are normally free from odor nuisance, they have been found objectionable for aesthetic reasons, and state health departments generally require lagoons to be at least 1000 ft from the nearest residence.

Considerable research is being done on sewage treatment in lagoons, and regulations are being changed to reflect new findings. Local regulatory agencies should be consulted for latest rulings.

This report is presented as information.

Report on Assignment 6

Railway Waste Disposal

J. L. Goss (chairman, subcommittee), H. E. Graham, C. F. Muelder, F. O. Klemstine, R. C. Archambeault, W. F. Arksey, J. M. Bates, D. E. Drake, J. L. Engler, Henry Parrish, Jr., W. D. Phelps, J. W. Zwick.

The following report on railway waste disposal pertains specifically to waste oil separators for enginehouse and servicing facilities.

Because of the wide attention being focused on pollution abatement and stream water criteria now published by federal and state pollution control agencies, the railroad industry will be expected to provide and maintain liquid waste treatment facilities to meet the new quality standards.

Due to the nature of operations around main shop areas, enginehouses and servicing facilities, oil and grease removal is most important in treatment of the industrial wastes. This is essential whether the wastes are treated for disposal to a municipal system or for discharge to a receiving stream.

Every effort should be made to separate the industrial waste from sanitary and storm drainage to reduce volume and eliminate materials that will interfere with the effectiveness of the oil-removal facility. Storm and roof drainage should be discharged to some natural drain area. Sanitary waste can best be discharged to a municipal or approved biological system.

Baffled sediment traps, either of wood or concrete construction, placed at various locations close to the source of oil pollution, serve a useful purpose mainly in trapping the sediment and thereby reducing cleaning maintenance of the sewer drainage system. Periodic cleaning of the traps is essential to their effectiveness.

The most common type of construction for oil and grease waste removal is the API separator. The functioning of this gravity type separator depends upon the difference in gravity of the oil and water. Velocity of flow, retention time, and design of the separator are important factors for effective performance. Also, the effectiveness of a gravity separator operating at a given flow rate depends upon the temperature of the water, density and size of the oil globules and the amount and characteristics of the suspended matter in the waste water.

Gravity separators should be maintained as free of accumulated oil and sediment as possible. Flight scraper devices or other mechanical means for skimming oil and removing sediment under service conditions are preferred. Information on design and operational characteristics of main line gravity separators can be obtained from the American Petroleum Institute's "Manual on Disposal of Refinery Wastes."

Experience has shown that a gravity separator will not remove emulsified oil or oil tied up in suspended solids. To comply with quality standards, it is therefore necessary in many cases to construct a secondary treating facility.

One method is secondary ponding, which involves the retention of waste water in a relatively large basin before discharge into a receiving stream or other disposal outlet. Secondary ponding is attractive when only a polishing treatment is required and when waste water has a low solids content. A disadvantage is the large area required for impounding and questionable results if the influent contains a relatively high oil content.

Clarifiers using the air-flotation process are used by a number of railroads and have proven highly effective in oil and grease removal. With high oil content in the waste water, this type of clarifier is used in series with gravity separators as a final clarification step. Packaged units are obtainable with capacities to 1000 gpm. Nominal ratings are approximately 2 gpm per sq ft of flotation area.

Air flotation is not effective in breaking emulsions unless used with chemical coagulation. Chemicals commonly used are alum, iron salts, activated silica, potassium permanganate, calcium chloride and others. Coagulant aids are highly beneficial in obtaining effective flocculation at lower chemical dosages; pH correction may be necessary to improve coagulation.

Air flotation pilot plants are commercially available on a nominal rental basis and their use is recommended to determine which chemical or combination of chemicals gives the optimum results and to evaluate overall effectiveness in obtaining a quality oil-free effluent.

This preliminary report is submitted as information, as it is the intent to revise and expand the assignment to include design criteria, unit costs and specific recommendations.

Report on Assignment 7

Cleaning, Sterilizing and Handling Drinking Water Containers

C. E. DeGeer (chairman, subcommittee), R. C. Archambeault, T. I. Gray, T. L. Hendrix, R. N. Johnson, R. D. Powrie, J. C. Roberts, E. R. Schlaf, J. E. Wiggins, Jr.

The following report, submitted as information, is concerned with the furnishing of sanitary drinking water containers. It is based on solicited answers to the problem, inspection of various cleaning facilities, discussions with commercial manufacturers, and viewing demonstrations of various commercial machines using commercial cleaners versus "homemade" cleaners and disinfectants.

CLEANING, STERILIZING AND HANDLING DRINKING WATER CONTAINERS

Providing sanitary, clean-appearing glass jugs or bottles to be used for drinking water containers can be accomplished in two ways: Use reuseable containers, or use single-time "throw-a-way" containers. If reuseable containers are used, they should be handled in a manner to insure not only that the containers are sanitary, but also to conform to public health codes and standards. The number of containers being handled will determine the extent to which the facility can be economically automated. For small quantities, a simple three-partition sink would be adequate. For very large quantities, fully automatic facilities can be made or purchased. Regardless of the size of the operation, the following basic standards should be adhered to:

1. Cleaning

a. Cleaning shall be done in a separated area used solely for cleaning and storing the containers.

b. The room should be painted white and have adequate lighting, drainage and ventilation.

c. If containers require an acid cleaning, this should be done outside of the cleaning room.

d. The installation should include a separate sink or piece of automated equipment for each of the following procedures:

(1) *Cleaning facility:*
Commercial or homemade cleaners can be used.

(2) *Rinsing facility:*
A hot water tap (if possible) and drain racks for the containers.

(3) *Sanitizing facility:*
Sanitizing shall be done with an approved commercial solution or chlorine solution containing a minimum of 75 ppm of available chlorine or by placing the containers over steam jets for a minimum of 5 min. Remember to sanitize corks or caps used. Do *not* rinse after sanitizing.

2. Storage Facility

Dust- and insect-free storage cabinets with white interiors and properly labeled doors should be provided and used solely for the storing of the sanitized containers.

3. Filling Facility

Filling facilities shall have an approved source of potable water, piped according to code, and a provision for filling the containers with the least amount of handling possible. The use of hoses should not be allowed. A plastic or foil covering should be placed over the top and the neck of the container to prevent touching any part of the container that can later come in contact with the water in the dispenser.

4. Transporting Facility

Containers shall be handled and placed into the dispensers in a sanitary manner by using a carrying device that will prevent contamination of the top and necks of the containers.

In addition to the physical equipment for cleaning and sanitizing, continual inspection, supervision and educational programs are necessary to guarantee a sanitary supply of drinking containers.

Although the preceding information concerning drinking glass water jugs to be placed in dispensers, this same procedure should also be used for portable water coolers.

Report on Assignment 9

Protective Coatings for Buried Pipe

J. W. Zwick (chairman, subcommittee), W. F. Arksey, J. L. Engler, J. L. Goss, T. I. Gray, H. Parrish, Jr., W. D. Phelps, Jr., J. M. Ryan, E. M. Walters.

Your committee submits the following report as information:

Ever since man developed metal working, he has been confronted with problems arising from corrosion due to the fact that Nature is constantly endeavoring to revert man-made metals to their original state. Recent estimates made by the National Bureau of Standards indicate the destruction by corrosion in the United States amounts to approximately $10 billion per year. Stated in a different way, the destruction by corrosion requires about 40 million tons of new steel per year to replace metals destroyed by corrosion.

A large portion of the pipelines which the railroad industry requires to serve their various facilities are placed underground, where the lack of easy observation most often results in corrosion problems being overlooked or minimized. These subsurface installations should receive special consideration and attention, for they are subjected to the usual destruction by corrosion, plus the possibility of additional damage by stray electrical currents, soil stresses, and bacteriological and galvanic actions.

In an endeavor to combat the destruction of metal by corrosion, many types of protective coatings have been developed over the years to isolate the metal from corrosive environments. Cathodic protection, a system which neutralizes or counter-balances the electrical environment, has been employed, sometimes by itself but generally more often in conjunction with protective coatings; also various chemicals have been used by adding them to corrosive-prone liquids or vapors to control or eliminate corrosion on the internal surfaces of metal pipe.

Since the cathodic-protection and chemical-treatment methods are already included in Chapter 13 of the Manual, the following will deal only with the protective coatings applied to the external surfaces of metal pipe.

In addition to the fiberglass-reinforced and paper-wrapped hot-applied coal-tar and asphalt coatings which have been considered to be standard protection against corrosion for so many years, we now have today new coatings developed by the chemical industry to chose from, which include the pressure-sensitive polyvinyl and polyethylene tapes, the coal tar pitch-epoxy resins, the polyvinyl, polyethylene and polypropylene extrusions, and the epoxy resins.

Protective coatings that will provide a main-line defense against corrosion and will perform this job economically and efficiently must have a certain number of properties to do the job, such as:

1. *High Adhesion:*
   High adhesion or permanent maximum bond is of the utmost importance; therefore, the coating must be capable of withstanding forces from soil stress, thermal expansion and contraction of the pipe, and must also resist damage to the coating due to careless handling, falling rocks, clods, and being pushed under streets, driveways, roads, etc.

2. *Toughness:*
   A good coating must resist damage caused by shipping, handling, and installation. Also the coating must not split, cold-flow, or stress-crack when stored outdoors and exposed to the elements.

3. *Good Electrical Properties:*
   A satisfactory coating must stop the flow of electric current off the pipe to prevent corrosion and retain this electrical property at a high level during the expected life of the pipe. This is especially important now that the high-voltage direct-current transmission systems using the the ground-return principle are being utilized.

4. *Chemical Resistance:*
   The coating must resist the attack of a broad range of commonly encountered commercial chemicals and chemical vapors, petroleum products, soil acids, alkalis and salts.

5. *Wide Temperature Operating Range:*
   The coating must not become brittle and easily damaged at freezing temperatures nor must it flow or sag in summer heat.

6. *Resistance to Bacteria, Fungus and Vermin:*
   Coating must be completely resistant to bacteria, fungi, and vermin attack. Also, it must resist root attack.

7. *Easy Application for Coatings to Be Applied in the Field:*
   Coating must be capable of being easily and uniformly applied in the field by unskilled workmen. Also coating must be easily repaired if damaged.

8. *Long-Term Stability of all Properties:*
Coating must be capable of resisting change in any of its properties so that the corrosion protection will not be lessened or eliminated.

There appears to be a definite trend away from the application of protective coatings in the field, particularly in the smaller pipe diameters due to the cost element and the facts that:

a. Coatings in most cases cannot be applied in the field under controlled environmental conditions as can be done in a mill or plant which eliminates the sand, dust and rain elements that must be dealt with in the field.
b. Plant-applied coatings normally result in a more uniform consistency of material applied.
c. Workmen for plant-applied coatings are normally more specialized in coating applications whereas field men are not.

In determining what protective coating should be used on a particular project, the coating requirements should be thoroughly examined with the idea in mind of obtaining the most economical and efficient coating for that particular job. And then, after the project has been completed, it should not be forgotten, but should be checked out from time to time to determine that the expected results are being obtained.

Report of Committee 22—Economics of Railway Labor

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°**R. W. Pember,** *Vice Chairman*
°**H. C. Minteer,** *Secretary*
°**W. B. Throckmorton**
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J. K. Gloster
†K. H. Hanger (E)
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R. H. Jordan
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E. T. Myers
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G. M. O'Rourke (E)
C. W. Owens
C. T. Popma
R. W. Priesendefer
M. S. Reid
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G. E. Scholze
H. W. Seeley
A. E. Shaw, Jr.
R. G. Simmons
J. S. Snyder
W. W. Squire
W. B. Stackhouse
John Stang
J. T. Sullivan
J. E. Sunderland, Jr.
W. A. Swartz
R. H. Uhrich
J. T. Ward
G. E. Warfel
H. E. Wilson
G. H. Winter
F. R. Woolford
B. J. Worley
C. R. Wright (E)

Committee

† Died June 1, 1967.
(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 22.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Analysis of operations of railways that have substantially reduced the cost of labor required in maintenance of way work.
   Progress report, presented as information .... page 196

3. Labor economies in the use of radio by maintenance of way forces.
   Final report, presented as information .... page 203

4. What various railroads have done to effect economies in track inspection.
   Final report, presented as information .... page 208
5. Economics of track labor in the maintenance of continuous welded rail, collaborating as necessary or desirable with Committee 31.
   Final report, presented as information .... page 210
6. Economics of maximum mechanization in yards and terminals.
   Final report, presented as information .... page 212
7. Labor economies of various methods of renewing ties in main lines with mechanized forces, related to the density and cycles of renewals.
   No report.

THE COMMITTEE ON ECONOMICS OF RAILWAY LABOR,
H. W. KELLOGG, *Chairman.*

AREA Bulletin 609, November 1967.

Kenneth H. Hanger
1884-1967

Kenneth H. Hanger, retired chief engineer, Missouri–Kansas–Texas Railroad, and Life Member of AREA, passed away at Little Rock, Ark., on June 1, 1967, at the age of 82. He is survived by his only son, F. Whit Hanger of San Antonio, Tex.

Mr. Hanger, the son of Frederick Hanger and Frances (Harrow) Hanger, was born in Little Rock on August 29, 1884. He was educated in the public schools of Little Rock, and was a prolific reader throughout his entire lifetime. He was married to Ree Winslow Hanger, now deceased. His father's ancestors were among the founders of Little Rock and his mother descended from a colonial Virginia family.

During his active career, Mr. Hanger contributed a total of 54 years to the engineering profession, with all but six months of it spent in the railroad field.

He entered service of the Choctaw, Oklahoma & Gulf Railroad, now part of the Chicago, Rock Island & Pacific Railroad, in 1900, as a chainman on a survey party. He advanced through subsequent engineering and maintenance positions on the Rock Island. He went to the M–K–T in 1920 as division engineer at Parsons, Kan., and was promoted to engineer maintenance of way on the Katy in 1924, with headquarters at Dallas, Tex. In 1944, Mr. Hanger was elected chief engineer of the M–K–T, with headquarters in St. Louis, Mo., serving in that capacity until he retired on August 31, 1954.

He joined the AREA in 1910, was made a Life Member in 1945, and was a Member Emeritus of Committee 22 at the time of his death. He was a member of the Mississippi Valley Maintenance of Way Club, American Society for Testing Materials, and American Wood Preservers Association, a Fellow of the American Society of Civil Engineers, a member of National Society of Professional Engineers and of the Engineers Club of St. Louis. He was a registered professional engineer in Arkansas, Missouri and Texas. He was active in the affairs of Christ Church Episcopal of Little Rock.

His more specific background and activities within the framework of AREA included service on Committee 12—Rules and Organization, from 1912 to 1915; Committee 2—Ballast, 1923 to 1928; Committee 22—Economics of Railway Labor, from 1936 to 1938 and again from 1948 to 1957, being made a Member Emeritus of Committee 22 in 1959.

Mr. Hanger was interested in and helpful to many young men interested in railroading, particularly to those in railroad engineering and maintenance, as well as those starting out in the railroad supply industry.

He was warmly esteemed by those who had an opportunity to be associated with him, and was genuinely respected for his contributions in the field of railway engineering and maintenance.

J. E. Eisemann, *Chairman*
C. G. Davis
W. B. Throckmorton
Committee on Memoir

Report on Assignment 2

Analysis of Operations of Railroads That Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work

M. H. Dick (chairman, subcommittee), E. R. Anderson, A. W. Carlson, S. A. Cooper, J. E. Eisemann, J. K. Gloster, J. O. Holladay, T. L. Kanan, R. A. Kendall, H. C. Minteer, E. T. Myers, C. W. Owens, G. M. O'Rourke, R. W. Preisendefer, D. F. Richardson, G. E. Scholze, A. E. Shaw, Jr., R. G. Simmons, W. W. Squire, J. E. Sutherland, Jr., John T. Ward, C. H. Winter, F. R. Woolford.

This report is submitted as information.

On July 18, 1967, in connection with a meeting at Albany, N. Y., Committee 22 made an inspection of the construction under way at the New York Central's Selkirk yard, which is 16 miles from Albany. The completed yard, which will be known as the Alfred E. Perlman freight yard, will cost $25,000,000 and will have 70 classification tracks. However, the yard is capable of being enlarged to 90 tracks.

Features of the Yard

The new yard will be an automatic facility and will comprise the fifth electronically controlled yard on the Central system. The control system for the yard will consist of two stored-program digital computers to provide automatic hump operation, to perform routine clerical functions and to provide a variety of management information. There will be two computers, each loaded with the same information. The second unit will take over in case the first unit becomes defective in any way.

One yardmaster will direct the entire operation. All information pertaining to the yard will be displayed in front of him. The communication network will include six closed-circuit television systems, three of which will be used to check car numbers on inbound trains. These will be equipped with video recorders so that a clerk need not be present when a train is being received in the yard. As the inbound train passes the TV camera station a recording will automatically be made. The clerk can then play back the TV record if necessary to double-check a car number.

A total of 12 radio systems will be provided, including train radio and general yard frequencies, four pullback train frequencies, and frequencies for maintenance of way and the diesel facility.

Supporting facilities will consist of nine-track receiving and departure yards, a 10-track local yard, a diesel repair and servicing facility, which alone will cost about $3 million, a car-repair facility which will include a single-span shed, 120 ft wide and 140 ft long, and a multi-level automobile unloading site, already in operation.

Welded rail in quarter-mile lengths, joined by thermit butt-welds in the field, is being used in the construction of much of the trackage, with jointed construction being used in the local yard and in some of the tracks in the classification yard. Secondhand rail in 105-lb, 127-lb and 136-lb sections is being used, although new 119-lb rail is being used in some locations including through the retarders. A pad of pit-run ballast, 8 in to 16 in thick, is being placed on the roadbed under all tracks, and 6 in of crushed stone ballast will be placed under the ties.

The track work was started on June 1, 1967, and was 5 percent complete at the time of the inspection. The grading, which will involve moving a total of 2,000,000 cu yd of material, was 65 percent complete. The project is scheduled for completion in July 1968.

Several features of the construction operations were of particular interest to Committee 22. One was the prefabrication of the turnouts at a central location and their transportation to storage or the point of installation. Another was the practice of fabricating jointed trackage into 39-ft panels. These features will be described in some detail. Other interesting activities will be dealt with more briefly.

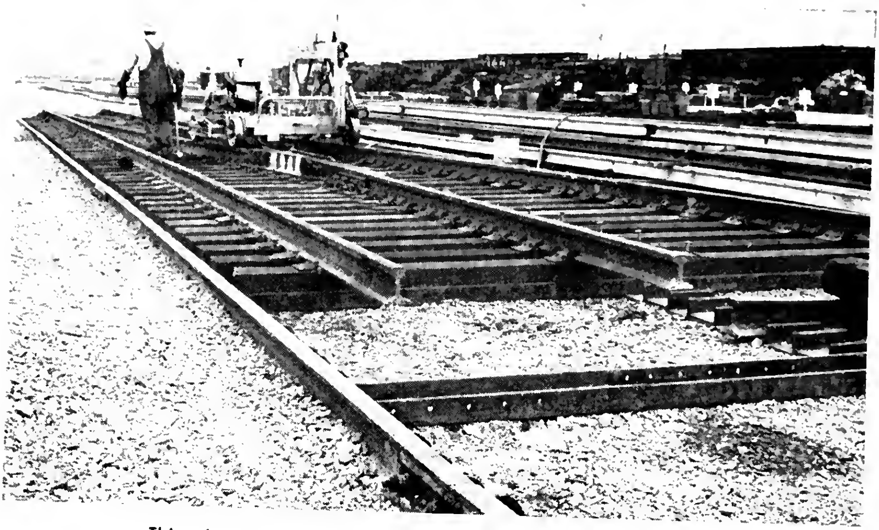
Prefabrication of Turnouts

Construction of the yard will involve the construction of 300 No. 8 turnouts and a much smaller number of No. 10's and No. 16's. These are being built with rail that had been butt-welded into quarter-mile lengths at another location on the NYC and shipped to the yard site in rail trains. Welded rails for the turnouts are cut into the proper lengths by a foreman and two men at a location in close proximity to the prefabrication site for the turnouts.

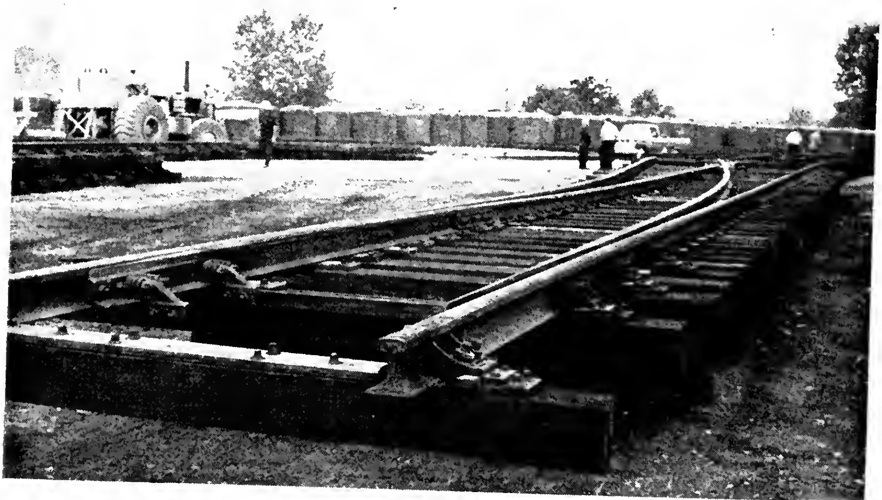
In the area set aside for fabricating the turnouts two jig assemblies are provided, which can be used for either right- or left-hand turnouts. No. 8 turnouts were being constructed and handled when the committee was present. These turnouts have switches 16 ft 6 in long, selfguarded frogs, 7¾-in by 13-in double-shoulder tie plates, new and secondhand switch ties alternating with each other and new and used rail anchors, with every tie being box-anchored. NYC spokesmen on the job explained that secondhand ties were being used as available. The secondhand switch ties being used were in good condition.

The jigs each consist of two parallel rails set far enough apart to handle the longest switch ties. Connecting these two rails at about every fifth switch tie are cross members consisting of steel channels. Along the center line between the two rails there is a timber sleeper on which is fastened channel irons cut to the width of

Jig for prefabricating turnouts at NYC's Alfred E. Perlman freight yard. More than 300 turnouts will be fabricated in this manner.



This view of turnout jig shows anchor applicator at work.



This turnout is fully prefabricated and ready for installation.

the timber. These channels and the cross-member channels all serve as receptacles for spacing the switch ties. The whole assembly is the length of the longest turnout to be fabricated, which is 130 ft.

The rail opposite the turnout side is used as a bumper or guide rail for squaring the switch ties before rail, frog, switches and tie plates are placed on the switch ties. The switch ties are set in place on the jig by a tie-handling machine with operator. Supplies of switch ties are placed on one side of each jig and tie plates and spikes on the other.

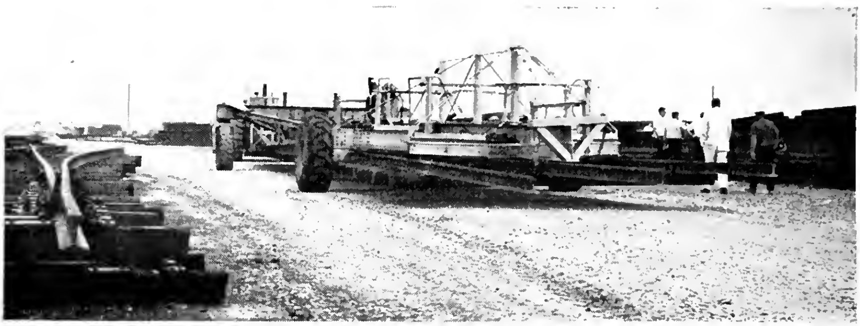
After the tie plates and switch plates have been placed on the ties, the rails, frogs and switches are set in place by a crane, two of which are available for various operations in the area. Since the rails have been welded and cut to length, the only joints are at the heel of switch and the toe and heel of frog. Spiking and rail-anchor machines are used for driving the spikes and placing the rail anchors. Because of the varying thicknesses of the secondhand ties, the switch ties must be nipped for spiking.

Fabrication of the turnouts is done by a foreman and six men. It was reported by NYC officers that two turnouts per day are produced by this force. Including all men involved in the entire operation, an average of about 60 man-hours is required to fabricate a turnout.

Carrier Used to Handle Turnouts

For handling the completed turnouts from the jigs to storage and thence to the sites of installation the NYC is using a large straddle carrier rented from the Elgin, Joliet & Eastern. This is essentially a four-wheel, rubber-tired buggy containing hydraulic lift cylinders for raising the turnout and holding it suspended at

Giant carrier, drawn by tractor, is used to handle completed turnouts to storage and thence to site of installation.



Rear view of turnout carrier with a turnout in the loaded position. Carrier was rented from the Elgin, Joliet & Eastern.

six points while it is being transported. The carrier consists basically of a long central beam, which is about the length of the turnout to be transported, and two main crossbeams which support hydraulic lift cylinders. The rear beam also serves as a bolster axle for the two rear wheels which have 17-ft centers. The picking up of the turnout is controlled by the operator who is positioned at control valves located at the center of the unit. At the pick-up points chains with hooks are fastened to the rails of the turnout.

The straddle buggy is pulled by a crawler tractor which positions the buggy over the turnout and also pulls the turnout to storage or its final location. The positioning of the buggy and the lifting of a turnout takes about 30 min. The buggy was said to have the capability of handling up to five turnouts a day to their final location.

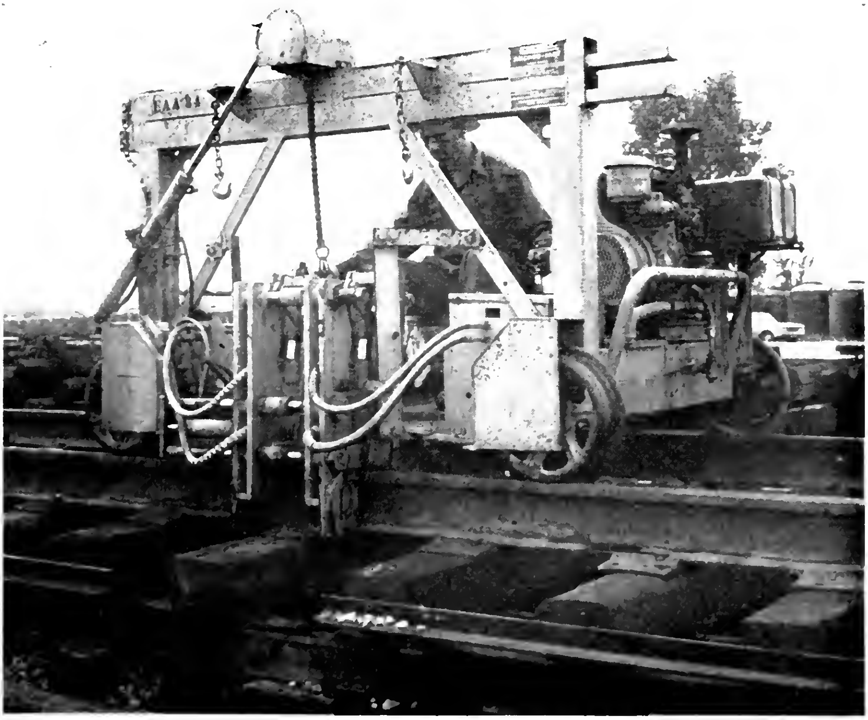
Prefabrication of Track Panels

One of the operations witnessed by the committee was the fabrication of 39-ft track panels for building tracks in the local yards and also some of the classification tracks. Fabrication of the panels, using secondhand rails, was being done on two parallel jigs, each 440-ft long. The jigs were so constructed as to allow for a tie spacing of 21¼ in. Each jig consisted of a piece of track with a steel channel placed longitudinally along one side, against which the ends of the ties are placed for alignment. Ramps at both ends of the jigs permitted track machines to move to and from them. Eleven panels were built at a time on each jig.

Materials were fed to the jigs from stock piles along both sides. Both new and secondhand ties were being used and were placed alternately in the panels. A tie-handling machine transferred the ties from the stock piles to the jigs, and the rails were handled into position with a crane. Other machines used in building the panels included two hydraulic spike drivers and two anchor-applicator machines, the latter being used one behind the other. Air lines were placed along the jigs to permit the use of air tools in the event of machine breakdowns. Completed panels are lifted from the jigs by a crane and loaded on flat cars for transfer to storage.

Personnel engaged in building the panels consisted of a foreman, an assistant foreman and 11 to 13 men. Supervisors on the job said that the production was 30 to 40 panels per day, but they expected that this output would be increased substantially as more experience was gained.

Jigs for prefabricating track into 39-ft panels. They are 440 ft long.



Anchor applicator at work on one of the track-panel jigs.

Inspection of the various operations at the yard was made on the day (July 18) that the railroad strike ended; hence, because the men were not yet back on the job in full force, most of the operation were not proceeding at their normal pace. However, the railroad had made a special effort to get the different jobs started and the committee was able to see most of them under way.

Following are brief descriptions of other operations or machines seen by the committee:

Shoulder ballast compactor—This track-mounted machine, constructed by the New York Central, consists of four vibratory road-fill compactors, two on each side, one just beyond the ends of the ties and the other farther out on the shoulder. They are adjustable to fit any desired ballast section beyond the ends of ties. The machine has two motors, one for propelling the machine and the other for operating the compactors.

This machine, which is normally worked behind a track-lining machine, is fully automatic and requires no operator. It is started by the liner operator and follows along behind the liner. When the compactor catches up with the liner a hinged control contacts the latter machine, causing the forward motion and compacting action of the compactor to stop. When the liner again moves forward the control is released and the compactor resumes its forward motion.

The object of the compacting action is to increase the holding power of the shoulder ballast in maintaining better line in butt-welded track. It is also pointed out by the railroad that compaction of the ballast shoulders with this machine decreases the voids in the ballast, preventing dirt from getting into it and tending to cause water to run off instead of penetrating the ballast section.

Retarder rebuilding and assembly—This involved an operation in which, using 119-lb secondhand materials, retarders were being assembled for use in the new yard. Worn parts were being rebuilt as required, using a process that involved preheating the worn part to a temperature of 400 deg and then applying a hard-

Members of Commitee 22 inspect an operation in which worn retarder parts are repaired by first heating them to a temperature of 400 F and then applying a hardfacing powder.

facing powder in the amount needed to restore the worn area. The units being assembled were 99 ft in length. It was reported by NYC personnel that, using a force of six men, a complete unit could be rebuilt ready for use in 10 days.

Switch tampers—One was an eight-tool machine with individual gun control. This machine uses hydraulic impact tamping guns, similar but much improved over the formerly used pneumatic tamping guns. The manufacturer states that it can tamp a No. 8 turnout in 40 minutes. This machine is equipped with jacking; however, it was not being used. The other was a machine incorporating vibratory tamping motors of which all parts are interchangeable with other tampers made by the same manufacturer. The manufacturer states this machine can tamp a No. 8 turnout in 20 to 25 minutes. This machine was not equipped with any jacking arrangement and as these machines were being used it was necessary to raise the turnout by other means than with this tamper.

Grading equipment—Seen in operation by the committee was a three-unit, 60-yd earth mover being used by a grading contractor on the job. Only one operator was needed. Another interesting unit was a 50-ton power pack being used by a contractor to compact new fills.

Conclusion

Partly because of the limited time available, but mainly because the demonstrations were made without the amount of man-power needed to properly exhibit the techniques, actual time studies by the committee were not possible. Even so, it was apparent that considerable savings in labor were being accomplished by the various techniques in use, especially the prefabrication of turnouts and track panels.

Report on Assignment 3

Labor Economies in the Use of Radio by Maintenance of Way Forces

W. J. Drunsic (chairman, subcommittee), A. D. Alderson, J. G. Begley, Arlie Bornhoft, J. L. Cann, A. B. Chaney, P. A. Cosgrove, C. G. Davis, L. E. Donovan, W. M. S. Dunn, F. J. Farish, Wm. Glavin, R. P. Howell, L. A. Loggins, J. M. Lowry, F. H. McGuigan, C. T. Popma, D. F. Richardson, J. T. Sullivan, W. A. Swartz, W. B. Throckmorton, R. H. Uhrich, G. E. Warfel, H. E. Wilson.

Your committee submits this report as information.

RADIO AND THE COMMUNICATION PROCESS

Communication is an important function in every business. It is particularly important in railroading because the physical plant used to produce service extends from hundreds to thousands of miles in length. It is the function of the maintenance-of-way department to keep its plant in a condition which will allow the transportation service to be provided efficiently and without interruption. Almost every single action by that department must be initiated by some form of communicated command or instruction. It is therefore imperative that all communiques be relayed as fast and accurately as possible.

On most railroads today, a wire-line phone system exists for the transmission of messages along the right-of-way. This system has inherent disadvantages, in that transmission and reception of messages can occur only at fixed points along the wire line and that a disruption in the wire line puts the system out of business.

Radio overcomes these deficiencies in its technical makeup by enabling the user, whether on the property or off, and whether near a phone or not, to contact other users of radio, provided they are within range and on the same frequency. While knowledge of the technical makeup of radio is not necessary to a potential user, the physical equipment involved and its capabilities and limitations are of interest.

Radio is of such a nature that a communications network may be built up as slowly or quickly as one desires or is able. Basically, equipment falls into three ranges.

There are portable, battery-powered sets of 1 to 5 watts output which have a very limited range. These sets are flexible in that they may be transferred from person to person or from vehicle to vehicle with relative ease.

Then there are the mobile units which are generally assigned to specific vehicles or equipment and receive their power from them. They are generally in the 12- to 25-watt output range.

A complete communications system requires the use of base stations which act as central transmitting and receiving stations and are constantly being monitored. Such a station is generally at a location where a large number of messages are originated and is usually tied into an antenna at some nearby point. These base stations serve as a relay between mobiles that are out of range of each other. Usually a radio system is set up so that when the standard mobile unit is out of range of one base station, it can be picked up by another.

The range of all radios will vary considerably. Besides power, other factors such as height of antenna, weather and the terrain affect the range of radios.

The designer of a radio communications system must first evaluate his communication structure. There are two areas which he must examine.

First, he will have to isolate the various operational levels that will use these facilities. In maintenance-of-way work, the following levels usually apply: Communication between (a) management with supervisory personnel; (b) supervisory personnel with maintenance forces; (c) supervisory personnel with program and special forces; (d) supervisory personnel with key people, such as, mechanics, truck drivers, operators, etc.; (e) end-to-end communications for program and special gangs; (f) supervisors with train dispatchers and tower operators; and (g) field forces with train dispatchers and operators. It is necessary to determine whether each of these channels occur in the track, bridge and building, signal, communications and maintenance-of-way departments.

Second, he will find that almost all communications in maintenance-of-way work will fall into one of the following categories: (a) the issuance of orders, (b) the issuance of instructions, (c) the issuance of vital information in relationship to the performance of a task, (d) the exchange of information relating to a given situation at a given time, and (e) the collection of routine data necessary for the compiling of various documents.

In determining where to use radio, it is necessary to decide what operating levels are to be covered. Then it is essential to evaluate the importance of the communication process to the operation and then to determine if radio will substantially aid in that process. The more that the communication is vital to the "production process", the greater the justification for improved means of relaying the message to the user of this information.

HOW ECONOMIES MAY BE DERIVED

When the communications process is aided or the physical system made more efficient, then economies should result. A survey of 50 Class I railroads indicated that some railroads are well along the way to the fulfillment of a total communication system, relying wholly upon radio, while others do not even have plans for employing the use of radio in their maintenance-of-way operation.

Of those railroads employing radio, very few conducted a formal study to verify the economies derived by the use of radio. Most maintenance-of-way radio users made their justification on the assumption of at least some of the following factors:

1. Elimination of antiquated communication facilities.
2. Manpower reduction.
3. Increased utilization of equipment and forces.
4. Greater flexibility of operations.
5. Improved supervisory control.
6. Emergency relay of information to train crews.
7. Reduced time delays to trains when passing work areas.
8. Increased safety of operations.

It is difficult to determine the savings on a dollar basis and thereby be able to translate the savings into a return on investment. However, without fail, every engineering officer felt that his organization had incurred substantial benefits from the use of radio, and most planned an expansion of their services.

In order to set up a program, let us review the specific areas where economies might be derived and how they may be measured.

1. Elimination of Antiquated Facilities

Primarily this means the elimination of all wayside phone lines. Greatest economies will result on low- to medium-density traffic lines where no form of automatic signal system exists, in which case, for the most part, the pole line exists solely for the carrying of the communication lines. The cost of a radio system for all departments has to be weighed against pole-line maintenance. A substantial manpower reduction should result since the expense of maintaining miles of line, including brush control, is eliminated.

Also, an advantage in the maintenance of a radio system is that, for the most part, the unit to be repaired is brought to the maintainer instead of the maintainer having to travel to the trouble spot, often by motor car, as is the case with phone lines. Generally, there is a substantial credit which results from the salvage of material from the wire line.

2. Manpower Reduction

Generally speaking, it is very difficult to equate savings with manpower reduction since hardly ever is there a person involved in maintenance-of-way operations who is engaged solely in the interchange of messages. However, as explained in Item 1, above, when troublesome, antiquated wire lines are eliminated and replaced by a new, modern radio network, a substantial reduction in communication forces should be realized.

3. Increased Utilization of Forces and Equipment

The general consensus of most of the replying engineering officers is that the greatest benefit is derived by the overall increased utilization of forces and equipment. All railroads have drastically reduced their maintenance-of-way manpower in order to keep pace with the economic demands put to them. At the same time, engineering officers have had to maintain the same plant for increased speeds and tonnage. Many factors have enabled us to accomplish this objective, the primary one being mechanization. In recent years, with so much emphasis being placed on smaller but expensive, high-production units, a much greater attention is being paid to the utilization of these units. As previously explained, improved communication will generally increase utilization and every minute of increased utilization can be translated into dollars.

In order to help determine priorities and savings, the operation should be divided into work units. A typical breakdown for the track department might be rail gangs, tie renewal gangs, surfacing gangs, welding gangs, smoothing gangs, on-track cranes, off-track equipment, etc. Then an anlysis must be made of their operations and communication problems. Areas that should be checked are inter-gang communications, type of territory they work in, i.e., CTC, ABS, MBS, and whether they generally work under bulletin orders or a permissive block.

It is in the area of temporary permissive blocks where radio has its greatest effect on increased utilization. It saves much time traveling back and forth to a phone and generally increases "on-track time" because of the instant communication factor, which allows for the greater coordination between maintenance-of-way and transportation personnel. Also, gangs that usually work under bulletin orders often have the need to take temporary permissive blocks because in order to do work they must foul an adjacent track.

Increased utilization also results when down time due to machine breakdown is reduced. When a piece of machinery breaks down, it is imperative that it be fixed promptly. Immediate contact with a mechanic is essential, and radio allows this. Machines in a gang generally work in clusters, therefore it is not necessary to equip each machine. Key machines should be selected and tied into the mechanic's unit.

One of the greatest factors in increasing the value of radios is in allowing them to be used in obtaining permission for track occupancy. Many railroads are not taking full advantage of radio by allowing it to be used for this purpose. Radio is only a physical means of transmitting and receiving messages. In performing this function, it is no different than the wayside phone or whatever physical system is in use at present. Therefore, the radio can be and should be used for this purpose where possible, providing that all the existing rules of the individual road are followed.

4. Greater Flexibility of Operation

Key people cannot respond to emergencies or changes until notified. In short, the sooner the message is received, the sooner the necessary steps will be taken toward corrective action. When personnel are in constant reach by radio, their planned schedule may be readily adjusted to meet the emergency. These situations are emergencies because they are causing delay to some other operation. Thus, economies result in the reduction of delay time and overtime.

5. Improved Supervisory Control

Radio allows field supervisors to keep in constant touch with their forces that are so equipped. Thus, when field forces need decisions or information from a supervisor and vice versa, this exchange may immediately take place when necessary. Again this benefit substantially aids in the reduction of delay time.

6. Emergency Relay of Information to Train Crews

If the railroad's transportation department is equipped with radio, it is advisable for maintenance-of-way forces to have access to their frequency. Thus, when a dangerous condition is found, it may be immediately relayed to the train crews and/or dispatchers and operators. The minutes saved may be the difference between bringing a train to a safe stop and a costly derailment.

7. Reduced Time Delays to Trains When Passing Work Areas

Usually working blocks are effectively extended between control signals even though the working area may only be a short segment of track. Often trains must travel at reduced speeds for a longer distance than is necessary. On single track it is possible to define boundaries to which a train may run. When the track is clear for passage, the foreman will okay that passage directly to the train crew via radio.

This effectively shortens the block, which should reduce the delay. It also aids in the increased utilization of the work force. This type of operation is predicated on the basis that direct radio communication between train crews and maintenance-of-way work forces is possible.

8. Increased Safety of Operations

Whenever an improvement can be made in communication, greater safety is a resulting by-product. Radio is particularly effective for providing protective flagging for large gangs and at derailments.

In flagging operations the flagmen have constant communication with the gang and are maintained a sufficient distance to give ample warning of approaching trains. This allows the gang to work safely until the last minute before ceasing operations and clearing the adjacent track of any fouling equipment. If for some unforeseen reason the gang cannot clear, they will have sufficient time to stop the train.

Often at derailments, two or three pieces of heavy equipment are simultaneously involved in the same operation. It is imperative that these machines be coordinated. Radio permits this and also avoids the confusion resulting from more than one person on the ground passing hand signals.

Radio is particularly valuable during snow-removal operations. Men do not have to struggle through drifts every time they have to talk to someone. Their means of communication is available on the machine or on the men themselves, allowing them to keep on working.

SUMMARY

The maintenance costs of any system must be evaluated in determining its economic return. Most radios now in use by maintenance-of-way departments are less than 5 years old. The annual maintenance costs of these sets are averaging $80 to $150 for battery-operated sets, including batteries, and $40 to $80 for externally powered mobile sets. This range is affected primarily by usage. Those railroads owning radios that are in the 5- to 10-year bracket indicated that maintenance costs increased considerably in this range. The minimum life expectancy of a radio should be 8 years, depending on usage.

For the most efficient operation, maintenance-of-way forces should be assigned their own frequency. At the same time, most units should have the transportation frequency available for their use. This setup avoids overcrowding of frequencies, yet allows interdepartment communication via radio when necessary.

In short, radio is an important tool more compatible with today's demands than present wire line systems. The economies available by employing radio in many cases are liable to equal many times the investment required. However, as with any system, the desired effects are dependent on the proper usage and assignment of the radios. Therefore, a thorough analysis must first be made to one's communication structure and its physical needs. Once in existence, care must be exercised to see that the system is used properly and according to FCC rules and regulations.

Report on Assignment 4

What Various Railroads Have Done To Effect Economies In Track Inspection

JOHN FOX (chairman, subcommittee), A. D. ALDERSON, E. R. ANDERSON, J. A. BARNES, A. S. BARR, J. F. BEAVER, O. C. BENSON, W. E. CHAPMAN, L. E. DONOVAN, L. C. GILBERT, R. B. HAYSLIP, E. Q. JOHNSON, W. J. JONES, T. L. KANAN, M. D. KENYON, J. A. NAYLOR, D. E. RUDISILL, H. W. SEELEY, W. B. STACKHOUSE, R. H. UHRICH, JOHN T. WARD, G. E. WARFEL, B. J. WORLEY, C. R. WRIGHT.

In handling this assignment, your committee has endeavored to ascertain what economies have been made in track inspection and in what manner everyday track inspection is carried out.

Replies to the committee's inquiry were received from 22 railroads covering in excess of 132,000 miles of track.

Prior to 1949 track inspection was primarily carried out by section gangs. Of the reporting roads, 18 had used section foremen and/or section gangs, one had used roadmasters and three had used track supervisors for this task. Today, track inspection is carried out by men assigned, generally, to carry out track inspection. Only four roads indicated that section foremen and/or section gangs are assigned specifically to do track inspection. The four roads reporting use of section foremen and/or section gangs indicated that these men carry out track inspection on light-tonnage lines.

The titles of men used for track inspection vary considerably. A few of the titles reported are: Patrolmen, Assistant Roadmasters, Track Supervisors, Inspection Supervisors, Inspection and Repair Gang.

Replies indicated that track inspection is carried out on light, medium and heavy-tonnage lines in about the same manner.

Previous to 1949, track inspection was carried out using track motor cars. Today, the reporting roads use track motor cars or highway–railway vehicles, or both. Seven roads reported they use highway–railway vehicles, 11 roads reported that track motor cars are used and four roads reported they use both track motor cars and highway–railway vehicles. One road indicated it is now changing over from track motor cars to highway–railway vehicles.

Before the 40-hour work week became effective, track inspection generally was confined to the length of the track sections of that time, which varied from 4 miles to 12 miles long. Four roads indicated, however, that track inspection was carried out on territories which ranged from 65 to 80 miles in length before adoption of the 40-hour work week. Today, the length of territory covered by track inspectors varies from 45 miles to a high of 270 miles. Eighteen roads reported a marked increase in mileage covered by track inspectors. Four roads reported no change. The average mileage covered by track inspectors today is 93 miles.

The number of employees used primarily for track inspection has increased on most reporting roads since 1949.

Inspecting track ties to determine the renewals required was generally done by section foremen and roadmasters prior to 1949. One road used tie inspectors. On the reporting roads today, track tie renewals are determined by tie inspectors on two roads, by supervisors only on 14 roads, and by section foremen and supervisors on six roads.

The inspection procedures for determining out-of-face rail programs, ballast programs and out-of-face surfacing and lining, have not materially changed since 1949. Reporting roads indicate that determination of such programs is in the hands of the engineering supervisory staff.

The need for spot surfacing and lining is determined by section foremen, track supervisors, roadmasters and engineering supervisory staff.

The need for rail joint welding and rail grinding is determined by welding supervisors, track supervisors, roadmasters and engineering staff.

Track inspection to determine if standards are being maintained is carried out on eight of the reporting roads by regional track supervisors or general roadmasters, on three roads by track supervisors, and on 11 roads by roadmasters and engineering supervisory staffs. Generally speaking, there has been little change in this practice since 1949. In some cases titles have been changed but the job remains the same.

In 1949, inspection to determine if the condition of track is up to standard was carried out by means of track motor cars, except for two roads which reported using both highway–railway vehicles and track motor cars for this purpose. Today, these inspections on five roads are still carried out on track motor cars, eight roads use both track motor cars and highway–railway vehicles and nine roads use highway–railway vehicles only. In addition, most roads indicated that inspectors ride trains to check track riding qualities. Two roads reported they are using track condition recording cars to determine the condition of their track.

CONCLUSIONS

Track inspection carried out by section forces, which was the practice prior to the 40-hour work week, meant that a number of working hours each day was spent by the majority of section forces in inspecting track. With the advent of long track sections, mechanized track gangs, high-production track machines and different work methods, coupled with higher labor costs, it became necessary to have track forces spend all their time in productive work. Track inspection, which is an extremely important function on any railroad, was assigned to employees whose prime responsibility is proper inspection.

It is not possible to place a dollar value on the economies which have taken place in track inspection due to the many improvements that have been made in quality of materials, improvements in work procedures and methods of inspection. All reporting roads indicate, however, that as a result of improved quality of track, a reduction in man-hours spent on track inspection has been realized over the past 17 years.

Track inspection by individuals assigned to a specific territory, who are trained observers and good trackmen, can produce economies for all railroads. The type of inspection required, frequency, type of vehicles and length of territory will depend upon the working problems, general condition of the property, climatic and geographical problems on the individual railroads, and no hard-and-fast rules will apply.

Report on Assignment 5

Economics of Track Labor in the Maintenance of Continuous Welded Rail

N. H. Williams (chairman, subcommittee), J. A. Barnes, Arlie Bornhoft, L. B. Cann, Jr., A. W. Carlson, J. A. Caywood, C. G. Davis, J. E. Eisemann, J. K. Gloster, C. R. Harrell, W. J. Jones, R. H. Jordon, M. D. Kenyon, L. A. Loggins, J. M. Lowry, A. L. Maynard, R. L. Mays, J. R. Miller, R. W. Preisendefer, Mike Rougas, A. E. Shaw, Jr., W. B. Stackhouse, John Stang, G. H. Winter, F. R. Woolford.

Your committee submits this report as information.

A questionnaire was addressed to the officers of 61 railroads in the United States and Canada. Few roads kept detailed cost records of comparative sections of welded and jointed track. There was agreement, however, that continuous welded rail reduced maintenance costs. To determine how this economic judgment was made, the reporting officers were asked to answer the questionnaire insofar as it was possible, with answers based on their field observations, experience, and general studies of this subject.

Comparative cost records on seven test sections on the Pennsylvania, Delaware & Hudson, Great Northern, and Santa Fe were studied. These records showed an average of 149 man-hours per mile of track was saved annually by the use of continuous welded rail. As rail end wear increases on the jointed test sections, the savings will be increased.

Reports from 10 roads indicated that an average of 62 man-hours per mile of track was saved annually by using continuous welded rail because bond wire maintenance, oiling joints, rail end welding, and slotting had been eliminated.

Ballast shoulders were increased by 12 roads while the remaining roads reported they were more insistent that a standard ballast section be provided and maintained for continuous welded rail.

In general there is no restriction on laying continuous welded rail on ballasted-deck bridges. Bulletin 584, February 1964, page 632, describes the Southern's use of sliding expansion joints where continuous welded rail is laid on long open-deck bridges. Replies to a question on this subject indicated that more roads were now coming to grip with this problem. Some roads reported that the use of continuous welded rail was restricted to open-deck bridges not over 300 ft in length, some not over 500 ft in length, while some restricted its use on open-deck bridges on curves, and some permitted no rail anchorage on the bridge. Some roads indicated that they are fastening the bridge ties to the structure and then placing rail anchors against these ties. The only uniformity in the replies to this question was that all roads placed four anchors per tie at each end of the bridge for a distance of 195 to

234 ft. Several replies expressed the opinion that continuous welded rail would increase life of the bridge ties by the elimination of joint shock problems.

Rail anchor patterns follow the recommendations in Bulletin 577, February 1963, page 479. A few roads use four anchors on every third tie rather than four anchors on alternate ties in the body of the string.

Buffer rails at insulated joints and between strings were used by nine roads, six of which reported this practice reduced insulated joint maintenance. Nineteen roads reported they did not use buffer rails, while 13 roads reported that they joined strings of continuous welded rail together by field welding.

No attempt to raise or lower rail temperatures when laying continuous welded rail under adverse temperature conditions was reported by 18 roads. Heating to raise the rail temperature was used by 7 roads. Weed burners and heated air hoods were used. During very hot weather 4 roads used chilled air hoods to reduce the rail temperature. A midwestern road stated that the use of whitewash applied early in the morning to a string of continuous welded rail kept the rail temperature 16 F lower at midday than rail not so protected.

Special rail transport cars, either owned or leased, were generally used. Speed restrictions varied from 30 to 45 mph when hauled in regular trains. Generally, 40 strings, each string approximately 1400 ft long, were carried.

Curve-worn rail was welded by most of the reporting roads for selected use; the rails being graded for wear, match, and installed in accordance with the tonnage rating of the line where used.

All replies to the questionnaire indicated no increase in personal injuries or increase in labor costs for personal injury prevention practices when handling and maintaining continuous welded rail.

A "grass roots" survey was made on a northern, a midwestern, and a southern road to secure the opinions of the people closest to problems involved in maintaining continuous welded rail. The replies showed that continuous welded rail is economical. A summary of their replies indicated that the joint area gave them their greatest problem; joint tie replacements, bolt tightening and bolt replacement, oiling of joints, bond wire maintenance, as well as material handling, were the items listed. Much less surfacing was required, they said, when they had continuous welded rail. On the basis of experience with maintaining continuous welded rail for 10 years, these people predicted that such rail would outlast jointed rail, giving at least 50 percent more service life. Another feature stressed by the people at this responsibility level was that the removal of defective rails from tracks was noticeably reduced because 40 to 75 percent of the defective rails removed from track had the defects in the joint bar area. Continuous welded rail reduced this problem.

It was about 1903 that continuous welded rail was originated in Europe. The first long stretches of continuous welded rail in open main line track in the United States were installed during August 1933 on the Delaware & Hudson. This rail is still in service. Some of the continuous welded rail laid in the later 1930's has worn out and has been replaced. The Delaware & Hudson has found the life of continuous welded rail to be twice that of jointed rail. It has found that out-of-face surfacing is not as frequently required as with jointed rail.

With continuous welded rail there is less labor used to relay rail because of its longer service life. Less labor is used to correct problems that originate at the joint. There is better conductivity of track circuits. Where continuous welded rail is laid on existing tie plates, fewer man-hours are expended than when jointed rail is used. There is a reduction in the number of man-hours used to change defective rails because continuous welded rail reduces the number of defective rails.

Bulletin 589, December 1964, page 259, describes a dual rail laying system which reduces material handling costs. By this method of installing continuous welded rail, the right-of-way is cleaned up daily and the material distributed while being applied.

The rideability of continuous welded rail is always better than jointed rail having identical surface irregularities.

It would be desirable for the roads that have computers available to them to have the computers programmed to accumulate cost comparison studies on this subject.

Report on Assignment 6

Economics of Maximum Mechanization in Yards and Terminals

J. W. Brent (chairman, subcommittee), A. S. Barr, J. F. Beaver, O. C. Benson, R. H. Carpenter, J. A. Caywood, W. E. Chapman, P. A. Cosgrove, L. C. Gilbert, R. B. Hayslip, R. P. Howell, E. Q. Johnson, A. L. Maynard, F. H. McGuigan, H. C. Minteer, C. W. Owens, R. W. Pember, C. T. Popma, G. E. Scholze, H. W. Seeley, R. G. Simmons, J. S. Snyder, John Stang.

Your committee submits the following report as information only. It gives the results of our investigation of the degree of mechanization at present and the economics of maximum mechanization of track maintenance in yards and terminals.

In pursusing detailed information concerning the present state of mechanization of yard and terminal maintenance and some information about the economics of mechanized maintenance as compared to older hand methods, questionnaires were sent to 40 railroads. Replies were received from 24. An evaluation of their replies leads to the following generalizations:

1. All roads reporting, except one, indicated that progress had been made toward maximum mechanization of yard maintenance. The percent of mechanization varied from 100 on one road to zero on another; the average for all roads was about 50–60 percent.
2. Most reporting roads feel that considerable savings have been made as a result of partial mechanization and indicate that yard maintenance costs could be further reduced from 25 to 50 percent with full mechanization.
3. The full benefits of maximum mechanization of yard and terminal maintenance are, to a great extent, dependent upon stabilized maintenance budgets, which will permit development of detailed, long-range programming and scheduling of yard maintenance.

The greatest degree of mechanization has been obtained in rail and tie renewals and track surfacing. This has been achieved largely by utilizing the same equipment and gangs organized for the same operations on main tracks. Yard forces have been reduced considerably as a result of using these mechanized gangs to perform these heavy maintenance operations. The section gangs which perform the daily routine maintenance tasks on most roads are equipped with, or have access to, such small machines as rail saws, drills, bolt tighteners, switch point grinders, etc. Consensus is that if more and better small, portable and inexpensive power tools were available, much more could be done to mechanize these routine jobs. The emphasis in this area is on cost, since utilization of additional equipment for these gangs would be relatively low and, therefore, the initial and operating costs must be low.

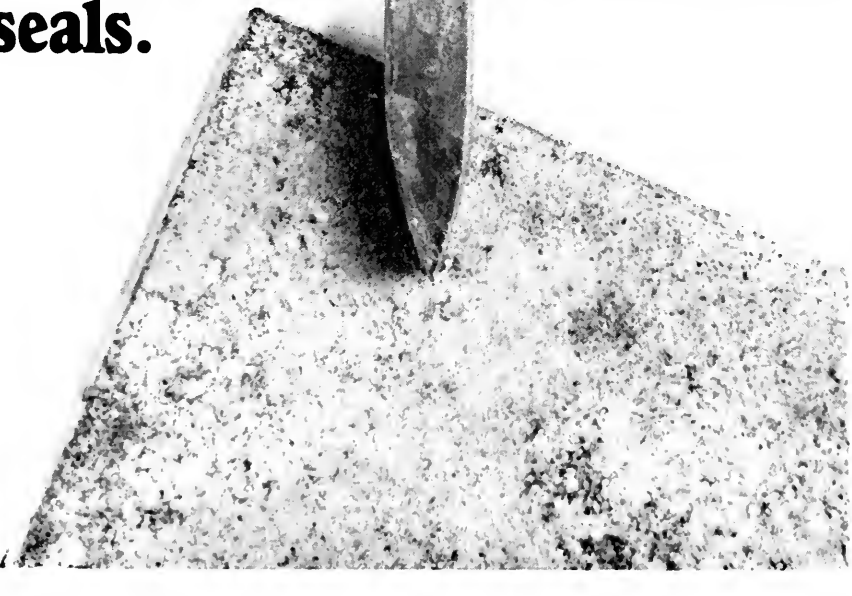
In order to justify the considerable expense involved in mechanizing yard and terminal maintenance work, the utilization of equipment and manpower must be relatively high. Most reporting roads indicate that they have great difficulty in obtaining sufficient working time to justify the use of large amounts of expensive equipment and manpower, and this is a problem which requires the complete cooperation of the operating department. Several roads which have progressed mechanization to the greatest degree, report that as mechanization has increased and the planning and scheduling of large maintenance projects has become more refined, support from top operating personnal in providing track time has been much more active. The direct benefits to the operating department resulting from extensive, planned yard maintenance programs are tremendous and can contribute considerably to reduced terminal operating costs.

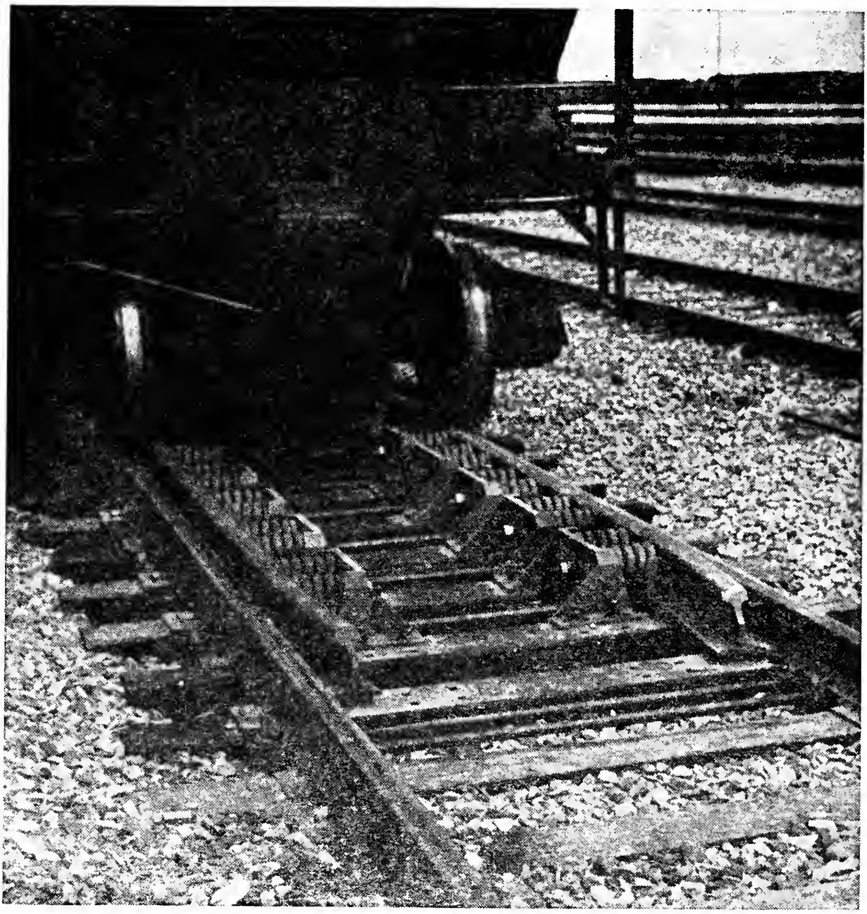
Track cleaning and snow removal are two areas where progress has been made in mechanization which has reduced costs and improved efficiency to a large extent; however, the equipment avilable for these operations is expensive, and maintenance and operating costs are still relatively high. Most reporting roads indicated that many more economies could be made in these areas if less expensive, more efficient units of equipment for these operations were available.

Most roads have concentrated on developing mechanized cycle maintenance programs for their main tracks and, even though yard and terminal maintenance has benefitted from this mechanization, much more could be done with the development of equipment and gang organizations specifically designed to perform yard work. Some of the recommendations received from the reporting roads for equipment not now economically available, were for machines to perform the following operations:

1. Yard tie and switch timber installation
2. Surfacing and lining turnouts
3. Track cleaning (smaller, less expensive machines)
4. Snow removal
5. Pneumatic tools and air compressors

It is not possible to express in terms of dollars and cents the economies already achieved or the total economies which would result from maximum mechanization of yard and terminal maintenance, since each yard or terminal is unique and has problems and possibilities not found in other locations. We can only conclude that partial mechanization has produced considerable real savings for the railroads and many possibilities still exist to obtain more economies as the degree of mechanization is increased.





Pages 14–2–1 to 14–2–19, incl.

PASSENGER TERMINALS

Reapprove with the following revision:

On page 14–2–16, in subparagraph (i) 2, add after the word "clips" in the third line, "however, better results will generally be experienced with rails installed on bearing plates and cushions", thus making the second sentence read: "The rails can rest directly on the concrete walls, if desired, without plates and cushions, and be anchored in place by bolted down rail clips; however, better results will generally be experienced with rails installed on bearing plates and cushions."

Pages 14–4–1 to 14–4–11, incl.

LOCOMOTIVE TERMINALS

Reapprove with the following revisions:

On page 14–4–8, in Sec. E. MISCELLANEOUS FACILITIES, insert a new Art. 6 to read:

"6. Fueling Stations

In the design and construction of fueling stations at diesel, diesel-electric and electric locomotive terminals, provisions should be included to prevent the pollution and contamination of public waters from spilled fuels and oils through surface and subsurface waters, sewers and other conduits."

Renumber present Art. 6 on page 14–4–8 as Art. 7 and Arts. 7 and 8 on page 14–4–9 as Arts. 8 and 9, respectively.

Manual Recommendations

Committee 15—Iron and Steel Structures

Report on Assignment 1

Revision of Manual

E. S. BIRKENWALD (chairman, subcommittee), T. J. BOYLE, J. L. DURKEE, G. F. FOX, E. T. FRANZEN, T. J. MEARSHEIMER, D. V. MESSMAN, R. D. NORDSTROM, D. D. ROSEN, G. W. SALMON, R. D. SPELLMAN, J. E. STALLMEYER.

Your committee submits the following revisions of specifications for adoption and publication in the Manual:

Pages 1–4–25 to 1–4–32, incl.

SPECIFICATIONS FOR CORRUGATED STRUCTURAL PLATE PIPE, PIPE-ARCHES, AND ARCHES

Page 1–4–26, Art. 4, Sec. B: Substitute the following:

4. Physical Properties

The minimum physical properties of the flat sheet or plate before corrugation shall be as follows:

American Railway Engineering Association—Bulletin

Bulletin 610 December 1967
Proceedings Vol. 69*

REPORTS OF COMMITTEES

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27—Maintenance of Way Work Equipment ------------- 329

The reports in this issue of the Bulletin will be presented to the 1968 Annual Convention of the Association at the Palmer House, Chicago, March 19–21, 1968. Comments and discussion with respect to any of the reports are solicited, and should be addressed to the chairman of the committee involved, in writing, in advance of the Meeting, or from the floor during the Meeting.

* The contents of this Bulletin and the other Bulletins of the Association from Bulletin 608, September–October 1967, to and including Bulletin 614, June–July 1968 (except Bulletin 613, March 1968), will constitute the Annual Proceedings of the Association, Vol. 69.

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Report of Committee 11—Engineering and Valuation Records

°**Howard R. Williams,**
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°**J. Bert Byars,**
Vice Chairman
°**R. S. Shaw, Jr.,**
Secretary
°**J. L. Manthey**
°**J. H. Robinson**
°**M. C. Wolf**
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J. J. Weisbecker
L. G. Weischedel
Louis Wolf (E)
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 11.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
Brief progress statement, presented as information . . . . page 217

2. Bibliography.
Progress report, submitted as information . . . . page 218

3. Office and drafting practices.
Final report on microfilming of engineering records and reports, submitted as information . . . . page 221

4. Special studies.
Progress report, submitted as information . . . . page 223

5. Application of data processing.
Brief status report and brief progress report as information on two studies underway . . . . page 224

6. Valuation and depreciation.
    (a) Current developments in connection with regulatory bodies and courts.
    (b) ICC valuation orders and reports.
    (c) Development of depreciation data.

    Progress report on two assignments is presented as information ...... page 226

7. Revision and interpretations of ICC accounting classifications.

    Only minor changes occurred this past year; accordingly, no report is submitted.

THE COMMITTEE ON ENGINEERING AND VALUATION RECORDS,
HOWARD R. WILLIAMS, *Chairman.*

AREA Bulletin 610, December 1967.

William S. Gates, Jr.
1899-1966

William S. Gates, Jr., retired assistant to auditor–general accounts and valuation, of the Chicago & Illinois Midland Railway, passed away at Springfield, Ill. on Sunday evening, August 7, 1966.

He was born on February 9, 1899, in Chicago, and attended Lakeview High School. In 1917, he enlisted in the United States Army, serving two years in France with the 108th Engineers. At the war's end he attended the University of Illinois.

Mr. Gates began his railroad career with the Atchison, Topeka & Santa Fe Railway but spent the major part of his 43 years of railroad service with the Chicago & Illinois Midland at Springfield, holding various positions in the valuation department until his promotion to assistant to auditor–general accounts and valuation, the position he held at the time of his retirement on February 9, 1964.

He joined the AREA in 1950 and was a very active member of Committee 11, serving as chairman of Subcommittee 5—Construction Reports and Property Records, and as secretary of the committee, the office he held at time of his retirement. He had a thorough knowledge of railroad accounting and valuation work, and possessed a wonderful personality—always eager to take time to talk with and help the newer and younger members.

Mr. Gates will be remembered as having been very active in church and school work, and as a member of the Board of Elders and various other committees. After his retirement from the railroad, he assumed the duties of comptroller and business manager of Eastern Christian College at Bel Air, Md.

He is survived by his wife, Christine, who lives in Springfield, three sons: William B., Lt. Commander Richard L., Dale S.; and four grandchildren. All of his many, many friends will miss Bill Gates, especially his associates on Committee 11.

F. J. MERSCHER
M. W. BONNOM
W. H. KIEHL
Committee on Memoir

Robert A. Lariviere, Sr.
1901-1967

Robert A. Lariviere, Sr., retired auditor–property accounts of the Chesapeake & Ohio Railway, passed away at Detroit, Mich., on Saturday afternoon, February 4, 1967.

He was born on June 4, 1901, in Ottawa, Ont., Can., and attended Seminaire de Joliette High School in Joliette, Que., and in 1920 received a B.A. Degree from Laval University. His education was continued at McGill University, Montreal, Que., in Civil Engineering.

Mr. Lariviere began his railroad career in 1921 with the Canadian National Railways as a rodman–instrumentman and continued his career with the Pere Marquette Railroad and the Chesapeake & Ohio Railway, where the major portion of his 45 years of service was spent. He held positions of engineering accountant, assistant engineer and cost engineer in the Valuation Department of the Pere Marquette. He was promoted to engineer-in-charge of the Valuation Department of the Pere Marquette District of the C&O and subsequently was promoted to auditor–property accounts in the C&O auditor of capital expenditure's office, the position he held at the time of his retirement on June 30, 1966.

He joined the AREA in 1960 and was an active member of Committee 11 since 1962. He had a thorough knowledge of railroad valuation work and in his very friendly manner freely passed this knowledge to other members of the committee and to his fellow employees.

Mr. Lariviere will be remembered as having been very devoted to his church and his family. He was a very active member of the Knights of Columbus, serving on many special committees. All of his many friends and associates will miss Bob, especially his associates on Committee 11 and those who had the privilege of working closely with him.

He is survived by two sons: Robert A. Jr., and John R., and two daughters: Sister Laetitia Marie IHM, and Mrs. Lewis Beaver (Pauline); and seven grandchildren.

Larry F. Grabowski, *Chairman*
Minus J. Hebert
Richard S. Shaw, Jr.
Committee on Memoir

Report on Assignment 1

Revision of Manual

J. L. Manthey (chairman, subcommittee), C. R. Berquist, P. J. Beyer, Jr., C. J. Cosner, N. Hammond, M. J. Hebert, J. J. Hoolahan, M. F. McCorcle, L. V. Milligan, M. L. Myers, Jr., C. F. Olson, F. A. Roberts, J. H. Robinson, R. S. Shaw, Jr., G. W. Smith, C. H. Stewart, H. R. Williams, M. C. Wolf.

Review of Part 1 of Chapter 11 is continuing.

Report on Assignment 2

Bibliography

J. B. Byars (chairman, subcommittee), P. J. Beyer, Jr., H. C. Boley, C. R. Dolan, J. A. L. Houston, L. W. Howard, R. D. Igou, J. L. Manthey, J. J. O'Hara, C. F. Olson, J. H. Robinson, H. R. Williams, M. C. Wolf.

Your committee submits the following report of progress, which presents additional references with annotations.

Accounting

Railway Age, February 27, 1967, page 74. "Revised Accounting System is called Key to Profits."

Railroads can improve decision making, profit planning and control through a drastic revision of the present Uniform System of Accounts, together with the employment of sharper accounting practices by individual companies.

Depreciation

Taxes, December 1966, page 893–897. "Depreciation Recapture—Plans and Problems."

An excellent appraisal of what has happened since December 31, 1961, at which time new rules on depreciation recapture were set up.

This discussion, by Robert H. Monyek of The Arthur Young and Company of Chicago, covers recent developments, potential future problems and the techniques we must develop to solve them.

Drafting

Railway Age, August 14, 1967, page 16–18. "N & W is high on aerial mapping."

Traditionally, railroad engineering departments have had to rely on earthbound survey parties in keeping their station and other maps up to date.

Due to a shortage of both field and drafting personnel, the Norfolk & Western Railway investigated a new technique developed by the Mark Hurd Aerial Surveys, Inc., Minneapolis, Minn., especially tailored to meet the needs of railroads for an economical method of producing up-to-date maps of their facilities. In this plan, maps are drawn from aerial photographs made with high-resolution cameras and film.

The science of photogrammetry is used to produce maps to conform to requirements of the ICC's Bureau of Valuation and in the scale of 1″ = 100′. N & W is very satisfied with the results.

Taxes

Railway Age, February 6, 1967, page 29. "ICC may start a tax-accounting case."

The objective would be to require conciliation of book-basis figures with reports that are filed for income-tax purposes. Such subjects as accelerated depreciation, guideline lives, investment tax credits, loss carryovers and other items allowed for tax purposes but not recorded in accounts, would be discussed.

Taxes, March 1967, page 227–233. "The Investment Credit—Investment Incentive and Countercyclical Tool."

A comprehensive analysis of the investment credit problem by John W. Cook of Ernst & Ernst of Cleveland.

The opponents of investment credit believe it to be inflationary and it should be suspended, while the proponents maintain that it is an anti-inflationary stimulus. Such opposite viewpoints indicate the need for extensive study and analysis.

The Journal of Taxation, August 1967, page 66–70. "Planning property acquisitions in view of the return of the investment credit," by Durwood L. Alkire.

The return of the investment tax credit as well as accelerated depreciation on buildings brings into play numerous transitional rules. Practitioners must be aware of these provisions if optimum tax results are to be achieved. The author, a prominent CPA from Seattle, analyzes the restoration provisions against prior legislation and offers tax men a guide to applying the new rules in practice.

Modern Railroads, July 1967, page 24–25. "Report from Washington."

A discussion of the changing tax picture resulting from the President's signing the investment legislation, and how there are still problems due to the economic uncertainty caused by such things as the escalation of the war in Vietnam and the proposed increase in freight rates.

This report also covers the latest congressional attitude on railroad tax discrimination within the states.

Office Procedure

Modern Railroads, September 1966, page 159. "MoPac Automates Records System."

The Missouri Pacific has completely renovated its record-keeping by making active records more accessible through use of microfilm and new filing and retrieving procedures, keeping channels open to semi-active records, systematizing filming, retrieval and return to file, and making inactive records non-existent while keeping in mind business policies and government regulations.

Railway Age, September 12, 1966, page 42–44. "NYC will refine its P & S computerization."

New York Central's Purchases and Stores Department has developed a computerized system known as MICA, Material Inventory Control and Accounting. This improved system gives instant answers on inventory when needed and provides accounting people with required data for efficient disbursement accounting.

Business Management, November 1966, page 51–56. "How to Ease into a Management Information System."

The rapid obsolescence of computer hardware plus the shortage of technical personnel, is leading many companies to take a new look at data processing. This article explores ways to avoid high equipment, personnel, and overhead costs while setting up an integrated management information system.

Business Management, December 1966, page 49–52. "Selective Dissemination of Information."

Managers swamped with information they don't need and unable to find information they do need can take heart from new developments in information technology. Inverted indexing techniques, mechanized files holding microfilm, reductions of documents, computer search and retrieval, television, photocopy or facsimile reproduction—are all being used to create systems providing selective dissemination of information.

Railway Age, December 5, 1966, page 42–43. "ACL Sets Up New Office Operation to 'Take a Letter'."

Atlantic Coast Line (now part of the Seaboard Coast Line) had set up a new central transcription bureau known as Dial Televoice System. Under this system letters, telegrams, etc. may be dictated by phone to a dial Televoice recorder link, then to a dial recorder unit and finally to a recording center in the bureau. An officer can dictate a letter at any hour and get it back ready to sign and mail in an hour. The system is not only a time saver and money saver but has many uses.

Microfilm in Business, by Joseph L. Kish, Jr. and James Morris (The Ronald Press Co., 156 E. 26th St., New York, N. Y. 10010) 1966, 163 pages, $7.50.

A comprehensive and fully illustrated book from which one may obtain any data pertinent to the microfilm system of record keeping.

Railway Age, March 13, 1967, page 18–20. "Computers: What They Learn is Only Human."

Frisco tries new approach to training the personnel who gather data for the electronic brain. It has set up a new school together with work in the field to accomplish this purpose. Using the conception that "the job isn't complete until the paper work is done" as a base, Frisco experts have written a manual which is used as a text for the month-long course. Employees are taught not only how to do the job but also why the job has to be done and why it is important that it be done right.

Business Week, June 17, 1967, page 66–70. "Industry Starts a Run on Microfilm Banks."

Information service companies which store reams of data on film are growing rapidly and have produced a booming new business. The basic tool is 35-mm microfilm, but the drive for data has brought refinements such as aperture cards—cards with a microfilm "window"—which can be tied into data-processing systems. The microfilm data bank has created the nucleus of a national information retrieval system. The new companies are now marketing information services as well as varieties of microimage equipment.

Reproduction Methods, June 1967, page 29. "A report on DuPont Crolux Film."

Consulting engineers use new photopolymer reproduction film for rapid reproduction of drawing duplicates without darkroom or chemical development. This method might be an effective way of reproducing valuation maps and other engineering prints.

Reprographics, August 1967, page 8–9. "Microfilm at Mack."

Efficient response to engineering drawing requests is a must in any modern production operation.

A new type of engineering information system has been developed by Mack Trucks. This new system is called the Micro-Processing System and the associated Satellite File Procedure. All phases of micro-filming, storage and retrieval are covered. The Mack system uses the following equipment: two microfilm cameras, three diazo copiers, seven thermal copiers, seven viewer-printers, 49 desk-top viewers, and the necessary auxiliary data processing equipment. This article fully explains the system and the resulting advantages.

General

Forbes, January 15, 1967, page 16–22. "The Comeback Is Getting Up Steam."

A comprehensive look at the railroad industry, present and future, emphasizing the unlimited potential for tremendous improvement resulting in greatly increased profitability.

Development Of Uniform Procedures For Establishing Construction Equipment Rental Rates.

A report of the Highway Research Board in which it develops uniform procedures for establishing equitable rental rates for equipment used in highway construction. These procedures may also be applied to maintenance work.

Management Services, January–February 1967. "A Decision Curve for Lease or Buy."

The decision of whether to lease or buy usually involves a series of complicated calculations. A new approach has been developed to simplify this analysis. It is called the Decision Curve Method which provides graphic representation of a breakeven analysis of lease or buy decisions, thereby permitting decisions to be made by "sight scanning." It relieves management of the tasks of explicitly stating an assumed rate of return that will be available on capital and of predicting a specific residual work.

Report on Assignment 3

Office and Drafting Practices

J. H. Robinson (chairman subcommittee), P. J. Beyer, Jr., J. M. Bourne, J. B. Byars, N. Hammond, P. J. Hendricksen, J. J. Hoolahan, W. A. Krauska, J. L. Manthey, M. F. McCorcle, F. J. Merscher, M. L. Myers, Jr., B. F. Nauert, R. S. Shaw, Jr., C. H. Stewart.

The following is a final report, presented as information, on the microfilming of engineering records and reports and the preparation and submission of "as constructed" or "as built" prints for AFE's or work orders.

MICROFILMING OF ENGINEERING RECORDS AND REPORTS

Progress reports on microfilming appeared in Bulletin 582, December 1963, pages 311 and 312; Bulletin 596, December 1965, page 195; and Bulletin 603, December 1966, pages 209, 210 and 211.

Previous reports have covered the desirability of microfilming, Interstate Commerce Commission requirements, and problems of storage for permanency. Your committee, in our final report on this matter, deals with the very important subject of cost.

Cost of equipment for microfilming can and will vary considerably. Cameras for microfilming can be obtained at prices ranging from $450 to $10,000. If the material to be microfilmed consists only of flat letters and reports ranging up to 11 in. by 17 in. in size, a continuous-flow camera might suffice. Where particularly clear and accurate copies are required and the material to be microfilmed has been folded in a file, then a planetary-type camera is best because of the use of a copy table on which a sheet of mylar film can be placed to keep the material flat and in position. For forms and reports up to 15 in. by 23 in. in size, a 16-mm camera is sufficient. If maps, plans or other items larger than 15 in. by 23 in. are to be microfilmed, a 35-mm camera is recommended. Planetary-type cameras are available with interchangeable units so they can be used as either 16 mm or 35 mm. Ceiling height of the room to be used for microfilming should be taken into consideration, as some of these cameras run as high as 13 ft. Most of the cameras on the market today are capable of producing reduction ratios from 12:1 to 30:1.

Processing of the film can be done by commercial houses, but this tends to delay completion of the reproductions, unless there is a continuing flow whereby the cameras can be kept busy while the different rolls are being processed. Charge for processing is generally nominal. Processors which automatically process the film range in price from $2,300 to $3,400.

The prices of inspection equipment to check on fuzziness and clarity of the negative range from $200 to $500.

A densitometer, which checks the exposure and density of the negative, will cost about $550.

For viewing the completed microfilm, a projection type viewer can be obtained. Reader-printers are available whereby one can read a blown up version of the negative as an 8-in by 10-in enlargement and, if desired, reproduce copies up to 18 in by 24 in. The equipment varies in price from $1,250 to $3,000. A projection-type viewer can be obtained for $500.

Mounters, for mounting single negatives on aperture cards, range from $500 for a hand-operated type to $4,100 for the automatic type.

The original film, to be stored for security reasons, should be of the silver negative type and costs about $40 for a 100-ft roll. The film for duplicate or working copy, diazo-type negative, costs about $6 for a 100-ft roll.

Acetate jackets for mounting cut negatives are available in various sizes. The cost of the 4-in by 6-in size is about $82.60 per thousand. Figure on about 2½ cents per insert as the cost of mounting.

One major railroad, after extensive study, contracted to have its valuation records microfilmed and mounted. This involved microfilming over 1,000,000 papers contained in some 200,000 files. After preliminary studies, tests and checks, it was decided to use 16-mm black and white film for most of the work and color film for the prints and plans that were color coded. The commercial company used two rotary cameras, two planetary cameras, and two reader-printers. Two rolls of film were exposed at the same time, with one roll being the security roll to be stored in a safe location; the other roll was cut and placed in the acetate jackets. For prints and plans, a reduction of 24 to 1 was used. Long or wide plans required multiple exposures.

Contract prices for this work were:

16-mm rotary microfilming—included original camera negative film—one roll of duplicate camera negative film, all preparation of the original documents and refiling of the documents .... $69.00/M exposures

16-mm planetary color microfilming—included original camera negative color film—one roll of duplicate color film, all preparation to original blueprints and the refiling of these documents:

Size—8½ in by 14 in and 11 in by 17 in .... 93.50/M exposures

Size—24 in by 36 in and larger .... 115.20/M exposures

Micro-thin jackets—4 1/16 in by 6 in, five 16-mm chambers with one ⅝-in index strip .... 53.85/M jackets

Micro-thin jackets indexing—Jacket index strip pre-printed with AFE or Work Order number .... 11.90/M index strips

Micro-thin jacket loading—of 16-mm black and white and color film .... 21.80/M chambers

All prices shown are per thousand exposures, jackets, jacket chambers, indexing or loading.

It was estimated that two-thirds of the cost was related to getting the files ready for filming. The average cost was 10 cents per exposure, which produced 2 images—one for storage and the other for filing in jackets.

The volume of records involved will vary with each railroad. Whether to acquire the necessary equipment and do the microfilming with company forces or have it done by contract is something each railroad will have to decide.

"AS CONSTRUCTED" OR "AS BUILT" PRINTS FOR AFE'S OR WORK ORDERS

Canvass of 34 railroads, with 24 replying, indicated that "As Built" plans are submitted usually for all AFE's or Work Orders covering changes in tracks, bridges or buildings. The "As Built" plans generally become part of the AFE file.

The procedure for preparation of AFE's or Work Orders, together with the property accounting that follows, varies with different railroads. Accordingly, a standard practice for preparation of "As Built" plans could not be established. It is thought, however, that the following procedures, if adopted, would be of benefit in maintaining property records and preparing reports required for AFE's or Work Orders.

1. AFE or Work Order file folder bear notation "Mapping Required" and space for initialing when party or department responsible for maintaining maps is notified of such requirement.
2. Valuation Department, or other department charged with responsibility of maintaining property records, be furnished print showing, by appropriate colors or symbols, all trackage constructed, retired, shifted, converted or otherwise rearranged for every AFE or Work Order.
3. The above-mentioned department be furnished print, or printed form, showing complete information as to actual construction of, or changes to, bridges and buildings for each AFE or Work Order. Location print should also be furnished indicating, by appropriate color or symbol, structures constructed, relocated or removed, including pipelines, pole lines, etc.
4. Standard symbols be developed for property constructed, removed, relocated, etc., to reduce cost and speed preparation of original location plan and reproduction of copies, by eliminating necessity of coloring original and copies.

Report on Assignment 4

Special Studies

M. C. Wolf (chairman, subcommittee), R. O. Bassett, H. C. Boley, C. E. Bynane, P. L. Conway, Jr., J. E. Hebbron, P. R. Holmes, R. D. Igou, W. C. Kanan, W. H. Kiehl, J. W. Laurent, J. W. McDonnell, F. J. Merscher, J. M. Morgan, J. J. O'Hara, C. F. Olson, F. A. Roberts, J. H. Robinson, G. S. Rogers, R. S. Shaw, Jr., E. E. Strickland, J. J. Weisbecker, L. G. Weischedel.

Your committee submits the following final report as information.

At the request of the ICC Bureau of Accounts a study was made of proposed accounting case, ICC Subject No. 489—Accounting for Concrete Ties Laid in Replacement of Wooden Ties.

The study produced the following conclusions:

The subject of concrete ties has been considered from an engineering standpoint by numerous roads and to date the matter of betterment has not been conclusively determined. For the most part installations of concrete ties have been strictly on an experimental basis.

The results of the engineering studies have not proven that concrete ties are superior in quality to wood ties, that they have longer life or that the overall cost is higher than the cost for wood ties. Moreover, there is not yet a standardization of tie and fastening design.

The committee was unanimous in recommending to the ICC Bureau of Accounts and the AAR General Committee that, in view of the limited number of concrete ties installed by a few roads on an experimental basis, no general rule by the Bureau of Accounts be issued affecting the industry as a whole, and Subject 489 should be withdrawn by the Bureau of Accounts.

Report on Assignment 5

Application of Data Processing

L. F. Grabowski (co-chairman, subcommittee on accounting phases), H. C. Boley (co-chairman, subcommittee on engineering phases), J. B. Byars, C. E. Bynane, P. L. Conway, Jr., C. R. Dolan, R. L. Ealy, W. V. Eller, M. J. Hebert, J. A. L. Houston, R. D. Igou, W. C. Kanan, W. H. Kiehl, J. G. Kirchen, W. A. Krauska, M. F. McCorcle, F. J. Merscher, L. V. Milligan, J. M. Morgan, B. F. Nauert, C. F. Olson, F. A. Roberts, G. S. Rogers, J. E. Stein, J. B. Styles, E. G. Terrell, J. J. Weisbecker, H. R. Williams, M. C. Wolf.

Your committee submits the following brief status report on our continuing study of data processing techniques for Authority for Expenditure (AFE) charges and a brief progress report, presented as information, on the application of data processing to Roadway Machines, R&E Account 37.

DATA PROCESSING TECHNIQUES—AUTHORITY FOR EXPENDITURE CHARGES

The application of data processing techniques to AFE charges and data accumulation has been surveyed with inconclusive results at this time. A number of systems or procedures are in use but they do not lend themselves to general summarization. The study will be continued for later reporting.

APPLICATION OF DATA PROCESSING TO ROADWAY MACHINES, R&E ACCOUNT 37

A survey and special study of application of data processing to R&E Account 37 —Roadway Machines, was conducted. The results of this study follow:

1. Purpose of Study

To keep the industry informed of progress in the data processing of engineering and property accounting functions, a survey of the railroad industry was made of activity related to R&E Account 37—Roadway Machines.

The survey indicated that the following items of information were either essential or optional insofar as property record keeping is concerned. The survey also indicated that the basic roadway machines record, which is essential to property accounting, contains many items of data that are also essential to other management concerns about roadway machines. Arrayed below is informational data being used in various mechanized systems in the industry:

INFORMATION REQUIRED FOR PROPERTY ACCOUNTING AND OTHER MANAGEMENT NEEDS

	Property Accounting Needs		*Management and Other Use*
	Essential	*Optional*	
Owner (for multi-company railroads)	X		X
AFE number—acquisition	X		
Valuation section		X	X
Division		X	X
Location		X	X
Date acquired (in service date)	X		X
BV-588 year	X		
Addition (or retirement—ER & VO 3)	X		X
Primary R&E account number	X		
Unit indication	X		X
Description or prefix code	X		X
Identification (railroad number)	X		X
Serial number (manufacturer's number)		X	X
Manufacturer		X	X
Cost (original cost and A&B)	X		X
Depreciation data—Book (ICC)		X	X
—Tax (IRS)		X	X
Retirement AFE number	X		X
Date retired (out of service date)	X		X
Salvage	X		X
Weight of machine		X	X
Rental rate—PPM 30-3			X
—GMA			X
—Railroad			X
Maintenance cost accumulation			X
Maintenance data (engine number etc. Time lost—maintenance servicing, field repairs, shop repairs, etc.)			X
Operation cost accumulation			X
Operation data (machine hours by category, i. e., servicing, maintenance, idle time, travel time, weather delay, train delay, in operation. Fuel, other supplies, etc.)			X

2. Use of Data

In addition to property accounting purposes the above data in various forms can be used for—

Machine utilization management (including rental use reporting)

Management of maintenance costs

Management of operating costs

Repair vs. replacement decisions

Management of job costs involving use of company-owned machines

Management of ownership costs

Lease vs. ownership decisions

3. Explanation of Items, General Information and Punched Card Layout

The punched card layout is optional with the system and data processing equipment being used. Suggested layout has been covered thoroughly in previous studies and accordingly is not repeated here (refer to 1961 committee report, pages 574–580).

COLLABORATION WITH THE SPECIAL COMMITTEE ON SYSTEMS ENGINEERING

The subcommittee is working with and reporting on the activity of Special Committee on Systems Engineering to keep our membership abreast of developments. Data processing activity developed in Assignment 5 will also be reported to the special committee for their consideration.

Report on Assignment 6

Valuation and Depreciation

C. R. Dolan (chairman subcommittee), G. R. Berquist, M. W. Bonnom, J. B. Byars, P. L. Conway, Jr., C. J. Cosner, R. L. Ealy, W. V. Eller, L. F. Grabowski, J. E. Hebbron, M. J. Hebert, P. J. Hendricksen, P. R. Holmes, L. W. Howard, N. J. Hull, Jr., R. D. Igou, J. W. Laurent, J. G. Maher, J. L. Manthey, L. V. Milligan, C. F. Olson, G. W. Smith, E. E. Strickland, J. B. Styles, E. G. Terrell, T. A. Valacak, L. G. Weischedel, H. R. Williams.

(A) CURRENT DEVELOPMENTS IN CONNECTION WITH REGULATORY BODIES AND COURTS

ICC Bureau of Accounts

The work of the ICC Bureau of Accounts with respect to valuation was principally in the area of railroad and pipeline indices and pipeline tentative and final valuation reports.

During fiscal year 1967, the Commission, Accounting and Valuation Board, issued tentative and final valuation reports for 78 pipeline carriers. The Commission also released the Schedule of Annual Indices for carriers by railroad and pipeline for the year 1966.

As stated in our prior report, all railroad and pipeline carriers subject to the Commission depreciation orders have been placed on a five-year cyclical review basis. During fiscal year 1967, the Commission Accounting and Valuation Board issued 28 pipeline, 52 railroad and 18 water carrier depreciation orders.

The total authorized personnel for the Section of Valuation and Depreciation for fiscal year 1968 is 19.

Railroad Advisory Committee on Equipment and Roadway Property

The Railroad Advisory Committee on Equipment and Roadway Property met for their annual meeting in June 1967, with representatives in the Engineering Branch of the Section of Valuation to formulate prices for indices for year 1966, which, as mentioned above, have been released by the ICC.

(B) ICC VALUATION ORDERS AND REPORTS

A special Ad Hoc Committee was appointed to review ICC Valuation Orders. The committee was made up as follows: C. R. Dolan (chairman), M. W. Bonnom, J. B. Byars, C. E. Bynane, P. L. Conway, C. J. Cosner, L. F. Grabowski, J. E.

Hebbron, R. D. Igou, L. V. Milligan, C. F. Olson, J. H. Robinson, J. E. Stein, H. R. Williams, M. C. Wolf.

The Ad Hoc Committee was appointed to consider the broad concept of revision of the Valuation Orders in light of present-day requirements. The review covering what is needed is to be considered from the standpoint of accounting, engineering and valuation as they relate to corporate property accounting needs and other corporate needs; in addition to the needs by the ICC and other governmental agencies for regulatory purposes.

The Committee in collaboration with the ICC has reviewed Valuation Order No. 1—Map Order, and has drafted and submitted a proposed revised order, which has been submitted to the AAR for further handling. The Committee will continue their assignment with a review of Valuation Order No. 3.

Report of Committee 18—Electricity

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°E. M. Hastings, Jr., *Vice Chairman*
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°L. A. West
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R. L. Henderson
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A. B. Miller
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S. R. Negley
H. F. Nelson
R. F. Pownall
A. G. Raabe
E. H. Reed
J. G. Renfrew, Jr.
B. A. Ross
J. J. Schmidt
E. B. Shew
E. L. Tennyson
V. E. Wannag
R. W. Werts
A. C. Zagotta

Committee

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those indicated by asterisks constitute the Engineering Division, AAR, Committee 18.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual, collaborating with Mechanical Division, AAR.
   No report. There are no Manual revisions this year.

4. and 8. Power supply, motors and controls, collaborating with Mechanical Division, AAR.
   The subcommittee has been reorganized and work has progressed on several assignments. A comprehensive report is anticipated next year.

5. Illumination, collaborating with Committee 6 and Mechanical Division, AAR.
   No report.

9. Electrolysis and electrolytic corrosion, collaborating with Committee 13 and Communication and Signal Section, AAR.
   No report. Subcommittee is being reorganized.

10. Wire, cable and insulating materials, collaborating with Mechanical Division, AAR.
    Progress report, submitted as information .... page 230

11. Electric heating, collaborating with Committee 6 and Mechanical Division, AAR.
    Study in progress. No report this year.

13. Railway electrification, collaborating with Mechanical Division, AAR.
Progress report, presented as information .... page 232

15. Relations with public utilities, collaborating with Committee 20.
Progress report, presented as information .... page 252

THE COMMITTEE ON ELECTRICITY,
F. T. SNIDER, *Chairman.*

AREA Bulletin 610, December 1967.

Report on Assignment 10

Wire, Cable and Insulating Materials

Collaborating with Mechanical Division, AAR

F. T. SNIDER (chairman, subcommittee), D. W. AIKEN, R. BURN, R. W. EGE, H. T. FOY, R. C. GREENE, P. O. LAUTZ, H. F. NELSON, A. C. ZAGOTTA.

Your committee submits the following report pertaining to wire, cable and insulating materials. All items are presented as information.

A. WIRE, CABLE AND INSULATING STANDARDS OF INTEREST TO THE RAILROAD INDUSTRY

Revisions have been made to numerous national standards during the past year to keep them in accord with current practice. A new specification has been issued for Metallic and Associated Coverings for Impregnated-Paper-Insulated Cables, IPCEA No. S-67-401 or NEMA WC2-1967, and is available from either organization.

The specification for chlorosulfonated polyethylene, submitted and approved for adoption into the Manual last year, was also approved by the Mechanical Division and is now available from the secretary's office as Specification No. 589.

B. REPORT ON NEW TYPES OF WIRE, CABLE AND INSULATING MATERIALS

No report on any new insulation material has been received this year.

Following is a tentative specification for high-temperature silicone rubber insulated locomotive and car cable.

Specification No. ____

Specification for Single Conductor, Silicone Rubber Insulated, 0–300 volt, 0–600 volt Glass–Dacron Braided, 125 C Cable for High Temperature Use in Locomotive and Car Equipment.

TABLE I

Component Parts	*Specification Requirements*
Size of Conductor and Shipping Lengths	As specified in the order
Material of Conductor:	
Soft annealed copper, tinned, or	ASTM B 33 (See Paragraph 3)
soft annealed copper, coated	ASTM B 189 (See Paragraph 3)
Stranding	In accordance with Table II, (see Paragraph 2)

Insulation—Silicone Rubber	IPCEA—NEMA R
Thickness of Insulation	In accordance with Table II
Tolerance	IPCEA—NEMA R
Braid—inner—Glass	
outer—Dacron	
Separator	See paragraph 4
Dimensions	See paragraph 5
Finish	See paragraph 6

1. Scope:

This specification describes single-conductor, heat resisting silicone rubber insulated, glass-dacron braided, extra-flexible cable for use in high temperature locations on locomotive and car equipment.

2. Stranding:

Unilay construction may be used if specified.

3. Conductors:

Conductor diameters shall not exceed the values given in Table II of this specification.

4. Separator:

A suitable separator shall be applied on sizes 36,760 CM and larger.

5. Dimensions:

The finished cable shall be uniform in diameter throughout its length, and the overall dimension shall not exceed the values given in Table II of this specification.

6. Finish:

The finish shall be a high temperature and moisture resisting silicone impregnating saturant. Printed on the outer surface shall be the manufacturer's identification, conductor size, and voltage rating.

TABLE II

Approx. Area (CM)	Approx. Size AWG	No. and Size Each Wire in Strand	Type of Stranding	Conductor Diameter (Inches)	Insulation Thickness 64th Inch (Mils)	Glass Braid (Inches)	Dacron Braid (Inches)	Voltage Rating	Maximum Cable Dia. (Inches)
2601	16	19/.0117"	Bunch or Conc.	.060	2 (31)	.005	.0075	0-300	.156
3831	14	19/#27	Bunch or Conc.	.070	2 (31)	.005	.0075	0-300	.166
6088	12	19/#25	Bunch or Conc.	.090	2 (31)	.0075	.0075	0-300	.191
10910	10	27/#24	Bunch	.123	2 (31)	.0075	.0075	0-300	.224
2601	16	19/.0117"	Bunch or Conc.	.060	3 (47)	.005	.0075	0-600	.205
3831	14	19/#27	Bunch or Conc.	.070	3 (47)	.005	.0075	0-600	.215
6088	12	19/#25	Bunch or Conc.	.090	3 (47)	.0075	.0075	0-600	.240
10910	10	27/#24	Bunch	.123	3 (47)	.0075	.0075	0-600	.270
14950	8	37/#24	Conc.	.140	4 (62)	.0075	.0075	0-600	[illegible]
24640	6	61/#24	Conc.	.180	4 (62)	.0075	.0075	0-600	.380
36760	5	91/#24	Rope	.220	4 (62)	.0075	.0075	0-600	.410
[illegible]	4	105/#24	Rope	.240	4 (62)	.0075	.0075	0-600	.430
50500	3	125/#24	Rope	.260	4 (62)	.0075	.0075	0-600	[illegible]
60600	2	150/#24	Rope	.325	4 (62)	.0075	.0075	0-600	.520

NOTE: At the option of the purchaser, the manufacturer's standard type of stranding will be acceptable providing that the conductor diameter does not exceed the values shown. The total number of wires shall be as specified, plus or minus one percent, except 150/#24 which may vary by minus two percent, providing that the conductor diameter does not exceed the values shown.

Report on Assignment 13

Railway Electrification

Collaborating with Mechanical Division, AAR

K. S. Niemond (chairman, subcommittee), G. B. Adams, R. J. Berti, L. W. Birch, W. F. Bowers, H. F. Brown, K. A. Browne, A. B. Costic, E. K. Farreley, B. C. Hallowell, E. W. Koch, R. N. Lane, C. F. Mulrenan, A. G. Raabe, B. A. Ross, E. B. Shew, E. L. Tennyson, V. E. Wannag, R. W. Werts.

Your committee submits the following progress report, as information, on the general subject of railway electrification.

13A—Develop Tri-Annually a Report on Physical and Operating Statistics on Railroad Electrification Systems—Domestic and Foreign

E. W. Koch, *Chairman*

Table I - Electrified Railroads Throughout the World
(Revised to approximately July, 1966)*

	ELECTRIFIED					NON-ELECTRIFIED	
Country	Route Miles	Track Miles	Voltage	System (A)	Contact (B)	Route Miles	Track Miles
Algeria						2,201	2,936
	234	290	3,000	d.c.	OH		
Argentina						27,319	34,109
	71	176	800	d.c.	3R		
	16	29	550	d.c.	OH		
Australia						25,146	31,248
	510	1332	1,500	d.c.	OH		
Austria (T)						2,462	6,669
	1330	--	15,000 &	1/16 2/3	OH		
			6,600	1/25	OH		
	15	16.5	800	d.c.	--		
	4	5	500	d.c.	OH		
	22	28	1,000	d.c.	OH		
	13	14	1,800	d.c.	OH		
	7	8	2,200	d.c.	OH		
	69	72	750	d.c.	OH		
	8	9	600	d.c.	OH		
	11	12	3,000	a.c.	--		
	17	36	850	d.c.	OH		
Belgium						2,155	5,987
	652	1703	3,000	d.c.	OH		
	354	520	600	d.c.	OH		
Bolivia (T)						1,865	-
	5.5	9.9	550	d.c.	OH		

Table I (continued)

	ELECTRIFIED					NON-ELECTRIFIED	
Country	Route Miles	Track Miles	Voltage	System (A)	Contact (B)	Route Miles	Track Miles
Brazil (T)						19,651	-
	347	30	15,000	d.c.	OH		
	1200	-	3,000	d.c.	OH		
	2	-	750	3 phase	OH		
	5.2	5.8	550	d.c.	OH		
	9	-	600	d.c.	OH		
Canada						45,805	63,447
	-	2	600	d.c.	OH		
	26	48	3,000	d.c.	OH		
	-	5	1.500	d.c.	OH		
Chile (T)						5,346	6,300
	239	386	3,000	d.c.	OH		
	16	-	2,200	d.c.	OH		
	118	-	650	d.c.	OH		
	29	35	600	d.c.	OH		
	--	156	550	d.c.	--		
Belgium Congo						3,170	3,786
	422	519	25,000	1/50	OH		
Costa Rica						212	435
	79	93	6,000	1/20	OH		
Cuba						2,656	3,955
	85	103	1,200	d.c.	OH		
	11	40	650	d.c.	OH		
Czechoslovakia (J) (T)						7,287	14,725
	901	--	1,500 &	d.c.	OH		
			3,000	d.c.	OH		
Denmark						2,255	3,577
	41	95	1,500	d.c.	OH		
Egypt						3,123	3,403
	15	33	1,500	d.c.	OH		
France						20,248	36,947
	4919	14256	25,000 &	1/50	OH		
			1,500	d.c.	OH		
	3.7	4.3	11,000	1/50	OH		
	3.5	3.7	3,000	a.c.3 phase			
Germany						27,274	53,896
	4086	10606	15,000	a.c.	OH		
	20.5	29	720	d.c.	OH		
	11.6	14	1,650	d.c.	OH		
	15	19	800	d.c.	OH		
	2.7	4.1	600	d.c.	OH		
	11	21	750	d.c.	OH		
	63.3	74	1,500	d.c.	OH		
	112	161	1,200	d.c.	OH		
	34	-	650	d.c.	OH		
Great Britain						16,221	43,694
	1652	3855	25,000/6,250	1/50	--		
			1,500	d.c.	OH		
			1,200	d.c.	3R		
			630/750	d.c.	3R		
			630/650	d.c.	4R		

Table I (continued)

Country	Route Miles (Electrified)	Track Miles (Electrified)	Voltage	System (A)	Contact (B)	Route Miles (Non Electrified)	Track Miles (Non Electrified)
Hungary						4,824	7,393
(T) (Q)	247	730	25,000 & 16,000	1/50	OH		
	66	-	600	d.c.	--		
India						34,910	53,711
	101	176	1,500	d.c.	OH		
	1204	3132	3,000 & 25,000	1/50	OH		
Indonesia						3,723	3,809
	65	99	1,500	d.c.	OH		
Italy						6,441	7,726
	4946	10631	3,600 &	3/16 2/3	OH		
			3,000	d.c.	OH		
	489	616	3,000	d.c.	OH		
	16	21	3,600	3/16 2/3	OH		
	22	25	11,000	1/25	--		
	96	116	1,200	d.c.	OH		
	78	94	3,300	d.c.	OH		
	37	-	2,600	d.c.	OH		
	7	-	800	d.c.	--		
	59	77	1,650	d.c.	OH		
	27	35	4,000	d.c.	OH		
	18	40	1,500	d.c.	OH		
	25	30	6,000	1/25	--		
	68	74	3,200	d.c.	--		
	21	22	1,400	d.c.	OH		
	8	10	1,350	d.c.	--		
	31	37	2,400	d.c.	--		
Japan (T)						8,637	15,149
	2628	7847	20,000 &	1/50&1/60	OH		
			600	d.c.	OH		
			1,500	d.c.	OH		
	320	--	25,000	1/60	OH		
	147	230	600	d.c.	OH		
	570	1090	1,500	d.c.	OH		
	870	476	600 & 1,500	d.c.	OH		
Luxembourg						125	288
	85	209	3,000 &	d.c.	OH		
			25,000	1/50	OH		
Mexico						12,437	14,947
	64	70	3,000	d.c.	OH		
	14	17	600	d.c.	OH		
Morocco						808	919
	449	571	3,000	d.c.	OH		
Netherlands						1,004	2,203
	1009	2340	1,500	d.c.	OH		
New Zealand (T)						3,234	--
	68	178	1,500	d.c.	OH		

Table I (continued)

Country	Electrified: Route Miles	Electrified: Track Miles	Electrified: Voltage	Electrified: System (A)	Electrified: Contact (B)	Non-Electrified: Route Miles	Non-Electrified: Track Miles
Norway						1,421	1,790
	1252	1628	15,000	1/16 2/3	OH		
	10	16	10,000	a.c.	OH		
	16	21	6,600	a.c.	OH		
Poland						15,580	(T)
	1133	(T)	3,000	d.c.	OH		
Portugal						1,757	2,339
	466	541	25,000	1/50	OH		
	16	34	1,500	d.c.	OH		
Spain						8,635	10,143
	1526	2585	1,350,1,500,& 3,000 6,000	d.c. 3/25	OH OH OH		
	58	65	1,500	d.c.	OH		
	12	14	650	d.c.	OH		
	25	27	1,300	d.c.	OH		
	119	123	1,200	d.c.	OH		
	17	19	6,000	d.c.	OH		
	12	13	600	d.c.	OH		
	34	37	3,000	d.c.	OH		
	84	108	500	d.c.	OH		
	23	27	1,600	d.c.	OH		
Sweden						3,753	5,802
	4311	6854	15,000	1/16 2/3	OH		
	66	96	1,500	d.c.	OH		
	285	378	16,000	1/16 2/3	OH		
Switzerland (T)						50.7	334
	2279	4377	15,000	1/16 2/3	OH		
	18	21	1,300	d.c.	OH		
	35	-	750	d.c.	OH		
	20	27	1,650	d.c.	OH		
	1.1	1.4	650	d.c.	OH		
	7.3	8.5	600	d.c.	OH		
	16	16	850	d.c.	OH		
	118	108	1,500	d.c.	OH		
	81	-	1,200	d.c.	OH		
	14	15	1,300	d.c.	OH		
	41	49	940	d.c.	OH		
	90	-	900	d.c.	OH		
	11	11	600/1,200	d.c.	OH		
	337	414	11,000	1/16 2/3	OH		
	14	-	800	d.c.	OH		
	5.8	6.7	725	3/50	OH		
	5.6	7	1,125	3/50	OH		
	13	-	1,000	d.c.	OH		
	12	14	830	d.c.	OH		
	17	-	2,200	d.c.	OH		
	3	3.2	700	d.c.	OH		
	2.9	3.2	1,550	d.c.	OH		
	18	-	1,700	d.c.	OH		
	23	29	1,250	d.c.	OH		

Table I (continued)

Country	Electrified					Non-Electrified	
	Route Miles	Track Miles	Voltage	System (A)	Contact (B)	Route Miles	Track Miles
Turkey (S)	17	44	25,000	1/50	OH	4,981	5,912
U.S.S.R. (T)	13,980	-	3,000	d.c.	OH	70,520	152,000
			1,500	d.c.	OH		
			25,000	1/50	OH		
Union of South African Republic	1887	4140	3,000	d.c.	OH	11,783	14,894
U.S.A. (T)						229,063	352,573
CMSTP&P	662	928	3,000	d.c.	OH		
CSS&SB	76	151	1,500	d.c.	OH		
EL	67	-	3,000	d.c.	OH		
IC	38	119	1,500	d.c.	OH		
KC	15	19	650	d.c.	OH		
LIRR	101	245	650	d.c.	3R		
NYC	60	358	600	d.c.	3R		
NYNH&H	83	376	11,000	1/25	OH		
PRR	644	2189	11,000	1/25	OH		
Reading	84	-	11,000	1/25	OH		

Notes

(A) If alternating current, phase and frequency are shown, i.e., 1/16.2/3 means single phase 16 2/3 cycles; 1/25 means single phase, 25 cycles, etc.
(B) OH means overhead contact; 3R - Third Rail; 4R - positive and negative contact rail plus running rails.
(J) Some of this mileage is being converted to the prevailing national system (3000 V, d.c.)
(K) Additional miles now under construction.
(Q) The earliest line to use "commercial frequency." (Kande System)
(S) First to adopt 25,000 volt, single phase, 50 cycle a.c., with overhead wire conductor for purely suburban operation.
(T) Incomplete

* Source - "Janes World Railways (9th Edition)

13D—Developments in the Field of Electrification—Domestic and Foreign

L. W. Birch, *Chairman*

Reflecting the attitude of the electric utilities toward railroad electrification, E. O. George presented a paper before the 1967 IEEE–ASME Joint Railroad Conference on "Railroad Electrification—Challenge and Opportunity," in which he relates the recent work of a committee of the Edison Electric Institute. Mr. George stated:

"What I have said so far in appraising the favoring trends and mutual benefits of railroad electrification explains in part why we in the electric utility industry and others are encouraged by the prospects it offers. However, though it in no way dims our interest and enthusiasm, we also recognize that many problems exist, the solutions to which must be worked out on a mutually satisfactory basis before we can move forward.

"Because of this, and because any approach to be effective would have to come as a result of a total industry effort, the electric utility industry established, through the Edison Electric Institute, a top level Railroad Electrification Committee. Reporting directly to the Institute Board of Directors, membership includes Mr. Tatum, president of the Dallas Power & Light Company, who is chairman; Mr. Kigar, president of the Detroit Edison Company; Mr. Manz, executive vice president of Consolidated Edison Company of New York; Mr. Shelby, president of the Pacific Gas & Electric Company; and Mr. Rincliffe, chairman of the Board of Philadelphia Electric Company who is also a member of the Board of Directors of the Pennsylvania Railroad Company. In addition, there is an engineering, rate and marketing Task Committee headed by Mr. Barrett Shew, chief electrical engineer of the Philadelphia Electric Company, of which I am a member.

"The general purpose of this committee was and is to determine the technical and economic feasibility of railroad electrification. Based on what appeared to be the major problem areas, specific objectives were established. These included:

- To determine the economics of railroad electrification.
- To study the technical problems and suggest solutions attendant to the supply of large varying single-phase load from three-phase commercial systems.
- To suggest financing arrangements.
- To suggest optimum tariff arrangements.

"Initially, committee efforts were directed to the basic engineering and supply problems associated with electric utility service to railroad electrification systems utilizing commercial frequency power. Considerable up-dated data was available in this area based on previous studies that had been made, and experience gained in the operation of such systems overseas.

"This study has been completed. Without going into detail, the general findings confirmed the economic advantages of commercial frequency systems, and established that there were no unsolvable problems relating to utility supply. As regards the ability of utility systems to handle the large, single-phase loads required, assurance was provided that no serious unbalancing would occur. Detailed analyses of both the presently electrified Pennsylvania Railroad and the New York Central's New York to Cleveland line, showed conclusively that current and voltage unbalance would be well within pre-established limits. In summary, the electric utilities large, interconnected systems can easily provide the energy requirements for extensive commercial frequency railroad electrification."

For a number of years, developments in railroad electrification have included big advances in the use of high-voltage, commercial-frequency energy in the distribution. France, England, Germany, Japan, Russia, Belgian Congo and other countries have built many miles of high-voltage railway distribution systems, mostly 25 kv, a-c with frequencies of either 50 or 60 cycles. The United States has had only one high-voltage experiment and that was in 1925–26 when the Detroit, Toledo & Ironton Railroad built 17 miles of 22-kv, 25-cycle line between River Rouge and Flat Rock, Mich., and used two motive power units for the purpose of shunting freight cars in this Detroit district (Fig. 1).

The DT&I used concrete arches, spaced 300 ft apart, for the support of simple catenary spans. This was a very light system, only 1.32 lb per ft, but performed quite satisfactorily throughout the life of the electrification.

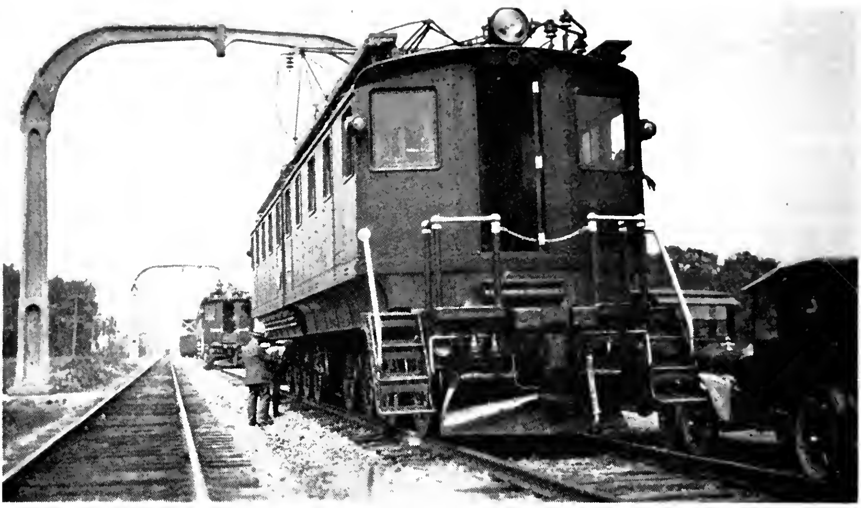


Fig. 1

Presently, a new high voltage, coal haulage railroad is being designed for the American Electric Power's Muskingum surface mine in southeastern Ohio. The coal is for the Muskingum River plant of the Ohio Power Co. and will be hauled in two trains of 15 cars each. These cars have a capacity of 100 tons. Two 5000-hp electric locomotives will pull these trains and will secure their energy from a 25 kv, 60-cycle simple catenary system supported on wood poles. Electric energy will be furnished by one substation. The line is 15 miles long. The trains will be completely automated and will operate at a top speed of 55 mph. The locomotives will carry their own rectifying equipment. (Fig. 2)

In the Pennsylvania Railroad's magazine of February 1, 1967, D. C. Bevan, chairman of the PRR's Finance Committee, pointed out that the Pennsylvania Railroad is spending $35 million for high-speed service between Washington and New York. The PRR has laid over 200 miles of welded steel rail within the eastern corridor area to accommodate these trains. A total of 50 new passenger cars will be acquired for the service which, according to Robert A. Nelson, director of the Northeast Corridor program, U. S. Department of Transportation, will require only 3 hr and 35 min between terminals. Today, most trains on this run take 4 hr and 15 in.

According to J. W. Diffenderfer, assistant vice president, Special Services, of the PRR, "the Pennsylvania Railroad plays a vital role in the Eastern Corridor.

"The Northeast Corridor Demonstration Program on the Pennsylvania Railroad has been designed to meet an immediate need. Cooperating with the Department of Commerce, the railroad is conducting a market research project, designed to measure and evaluate such factors as the public response to newer equipment, higher speeds, variations in fares, improved comfort and convenience and more frequent service."

Fig. 2

The U. S. Department of Housing and Urban Development has granted New York's Metropolitan Commuter Transportation Authority $22.6 million to be used for improvements on the Long Island Rail Road. Work contemplated includes upgrading the existing electrification and for the extension of electrified lines from Mineola to Hicksville and from Hicksville to Huntington on the Port Jefferson line.

The initial program includes 270 new high-speed electric passenger cars. Specifications call for a maximum speed of 100 mph. Cars will be 85 ft long, coupled in two-car units. Each car will be equipped with a public address system and two-way radio between crew and wayside.

Where the expense of electrification can't be justified, the Long Island expects to replace the slower-accelerating diesels with a unique type of car that will be turbine-powered in non-electrified areas but use third-rail power for the rest of the trip. This car, scheduled for preliminary tests on the Long Island's main line in 1968, will permit through service from the eastern end of the Island right into the heart of Manhattan.

Dr. William J. Ronan, chairman of the Metropolitan Commuter Transportation Authority, announced on July 5, that an application has been filed with the U. S. Department of Housing and Urban Development for a $1 million demonstration grant to test the dual-powered railroad car that would be capable of traveling at high speeds in both the electrified and non-electrified zones of the Long Island.

The Federal grant would represent two-thirds of the total $1.5 million required for the program.

Dr. Ronan said the new dual-propulsion tests involve a second phase of experiments with the world's first turbine-powered railroad car. "The experience of the initial test program, which used a gas-turbine engine with a mechanical transmission, has encouraged us to move ahead to this second phase of tests."

Adaptation of the car to a bi-powered system would permit the railroad to operate the same train under turbo-electric power in the nonelectrified areas and switch over to third-rail electric propulsion with no loss of speed or operating efficiency. This achievement could assure high-speed service throughout Long Island and help eliminate present operational delays caused by switchovers from diesel power to electric trains at Jamaica. These switchovers are required because only electric-powered trains are permitted to go through the East River tunnels into Pennsylvania Station.

The 5.2-mile Fox Chase commuter electrification of the Reading Company is showing a 14 percent increase in riding for the first year over the previous method of propulsion.

FOREIGN RAILROAD ELECTRIFICATION

The following is Press information from Engineering in Britain Information Service:

Developments in overhead equipment were discussed at the London Conference on Railroad Electrification a year ago. These are excerpts from the EBIS report.

"A major advance in the overhead equipment itself is the development of simple catenary equipment suitable for train-speeds up to 100 mph. Previously, compound or stitched catenary equipment was considered essential for speeds above 75 mph. In the new equipment, variations of stiffness are reduced by introducing a sag, amounting to about 3 in at mid-span into the contact wire, and by varying the spacing between hangers, which are reduced in number from ten to six per 200-ft span.

"Probably the most important single contribution is the reduction of electrical clearances for the overhead wire from original figures, based on U.I.C. specifications, of 11 in normally and 8 in during passage of a train, to new figures of 8 in and 6 in, respectively. The reduced clearances were proved safe by exhaustive tests in 1962, and are likely to be adopted by the U.I.C. in the future. On the London–Manchester–Liverpool lines they saved £1 million by making alterations to bridges unnecessary, and avoided the need for sections supplied at a lower voltage than 25 kv, so that voltage-selection equipment could be omitted from the locomotives."

In London, electrification of two miles of line has brought the London Freightline terminal into the electrified system, enabling Freightliners for Manchester and Liverpool to be electrically hauled throughout their journeys (Fig. 3). Freightliners—high-speed, permanently coupled trains of flat wagons carrying road/rail containers and running to a regular timetable, now carry 1000 loaded containers a week on six inter-city services. By 1969, the rate is expected to be 1500 containers a day; and ultimately there will be 100 routes and over 40 terminals.

Electrification of the London–Southampton–Bournemouth railway line in southern England was completed on March 6, 1967, and full electric services were intro-

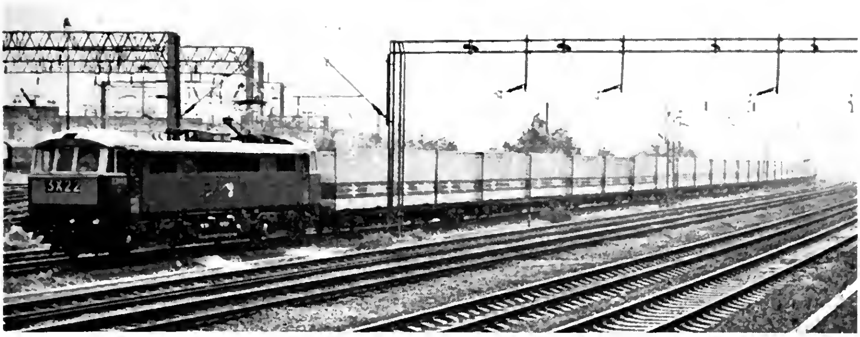


Fig. 3 (above)

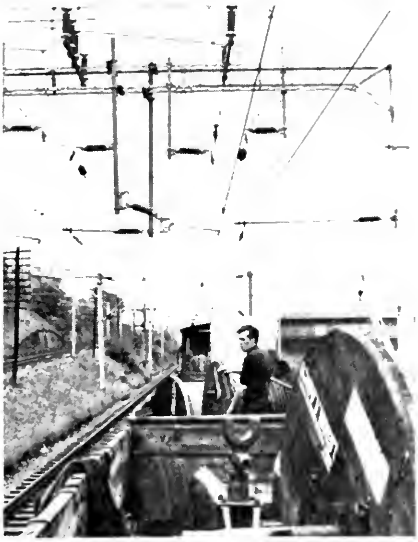


Fig. 4 (right)

duced on July 10. These will reduce journey times, on average, by one-sixth and the intensity of service will be approximately doubled.

Push/pull working will be used for the first time in Britain on the new line; 12-coach express trains will be propelled from behind in one direction, and hauled in the other, both at speeds up to 90 mph, by four-coach 3200-hp electric motive power units. The rest of the services will be provided by conventional multiple-unit stock and by electro-diesel locomotives which are electric locomotives carrying a 600-hp diesel engine for use on non-electrified lines. The system of electrification, as throughout British Railways' Southern Region, is 750 v, d-c, third rail.

The 8½-mile Isle of Wight d-c electrification was also completed on March 6 and electric services began on March 20.

The electrification of 37 miles of suburban railway (Fig. 4) running from Central Station, Glasgow, through the industrial area on the south bank of the River Clyde to the coastal towns of Gourock and Wemyss Bay was completed in February

Fig. 5

1967. These will be much more intensive and 30 percent faster on average than present steam and diesel services, and are expected to produce a 95 percent increase in passenger traffic by 1970. Two earlier suburban electrifications in the Glasgow area, using the same system of single-phase a-c at industrial frequency, each resulted in a trebling of traffic within five years.

Construction work on the latest project began in 1965 with the drilling of foundation holes up to 3 ft 6 in diameter and 12 ft deep by a rail-mounted auger. Where outcrops of rock prevented drilling to the full depth required, expanding bolts made of high-tensile steel were drilled into the bedrock to anchor the concrete foundations that were later poured around them. Altogether, some 5000 cu yd of concrete were poured into nearly 2100 foundations alongside the 70 miles of track. Heating of water and aggregate on the special concreting train before mixing enabled work to continue in frosty weather.

Next some 900 tons of galvanized steelwork were erected by rail-mounted cranes. In some difficult locations hinged structures were used, and in others, structures were attached to the walls of cuttings, the parapets of viaducts or to roof members in stations. Finally, the overhead wiring was installed, great care being needed in two low tunnels to ensure adequate clearance for the contact wires. The wiring was of the sagged simple catenary type in which the contact wire is given a sag of approximately 3½ in at mid-span and there are six dropper-wires per span instead of the former ten. This is quicker to erect and cheaper than the earlier type of equipment and provides much better current collection at high speeds. Other valuable technical innovations included gas-pressurized hydraulic cylinders for automatic tensioning of the equipment, and galvanized ferrous fittings with simple "hook & eye" connections.

The copper catenary and contact wires are supported by non-ferrous fittings. Nineteen three-coach, multiple-unit train sets with a top speed of 75 mph will be used on the new line.

South African Railways has ordered 358 electric multiple-unit coaches, 98 motor coaches and 260 trailer coaches for suburban services in Natal and western Transvaal. The coaches themselves will be built in South Africa while 3000-v, d-c electrical equipment will be supplied by two British companies. The new stock is due to enter service in February, 1968, and is similar in most respects to that ordered previously for suburban services at Durban and Capetown (Fig. 5). Trains can be made up with a ratio of up to three trailer coaches for every motor coach, and have a maximum service speed of 60 mph.

OTHER FOREIGN RAILROAD ELECTRIFICATION PROJECTS

A new electric locomotive, Type RE 4/411, has been developed for the Swiss Federal Railways for hauling heavy passenger and fast freight trains over the plains and, with two units, on mountain grades.

Power supply is single phase a-c, 16 2/3 cycles, 15,000 v, rating 6340 hp, 1-hr rating; maximum speed 87 mph. Also, four pantograph-equipped dining cars, taking power from western Europe's four supply systems, have been installed.

The French National Railways had 5321 route miles of electrification at the beginning of 1967. Plans for the current year were to proceed with modernization of motive power along established lines. These plans included 16 d-c locomotives, 20 dual-voltage locomotives and the receipt of 5 additional locomotives, remainder of an order for 55. A few other locomotives are still on order.

Electric trains carry 72.5 percent of the total traffic.

The eight new quadri-current locomotives of the Belgian National Railways operating on the Trans-European Express secure 25 kv, 50 cycle, energy in France, 3000 d-c in Belgium, 15,000 v, 16.6 cycles in Germany and 1500 v, d-c, in Holland.

Operating conditions in northern Sweden and Norway are exceptionally severe, requiring the most powerful locomotives in the world for heavy ore traffic. The Norwegian State Railway has recently installed the first of six silicon rectifiers of 7350 hp, 1-hr rating. The locomotives will be coupled in pairs, providing nearly 15,000 hp and receive electrical energy at 15 kv, 16 2/3 cycles.

The Italian State Railway recently purchased four electric locomotives for 3000 v, d-c, with an hourly rating of 4400 hp and a maximum speed of 110 mph.

Russia's 400 mile Abakan–Taisket line was placed in operation this year. The line forms the most easterly section of the south Siberian main line. Winter temperatures reach as low as —70 F. Average snow coverage is 6 to 9 ft. Trolley voltage is 25 kv at 50 cycles.

The German Federal Railway placed in operation last winter three additional electrified routes, increasing the total electrified mileage to 4325 miles. At present, plans for the electrification of the Black Forest Railway are being considered. Total mileage is 193.

The Swedish State Railway is receiving delivery of 20 thyristor locomotives representing the first application of thyristors to the series production of locomotives for 15 kv, 16 2/3-cycle lines. Their use provides very smooth acceleration. The 1-hr rating of the locomotives is 4900 hp and the top speed is 83 mph.

The first electrified lines in the Bombay area of India (1925) were equipped with 1500 v, a-c supply, while in Calcutta (1954), 3000 v, d-c was selected. When it was decided to continue electrification construction in the Calcutta region, experience gained elsewhere with high voltage a-c traction was sufficient to adopt a-c rather than 3000 v, d-c. The Government thinks that if the transport demands expected in India come about, these could be met by a proven 25 kv, single-phase, 50-cycle system. Standardization of this voltage and frequency was accepted for future electrification on the Indian Railways. By the middle of 1966, a total of 2978 track miles had been energized with this voltage and frequency. During 1967, 1462 track miles have been in the process of electrification with the high-voltage a-c system.

For several years, Czechoslovakia State Railways has been increasing the electrified mileage with 25-kv, 50-cycle trolley voltage. Train sets for districts requiring six coaches or less on passenger runs have become standard. Locomotives are used for longer passenger trains and for freight. The train sets, consisting of two motor cars and two trailers, have a top speed of 100 mph.

The Danish State Railways ordered 75 two-car units to improve and extend suburban service in the Copenhagen area.

The Hellenic States Railway has placed an order for nine electric train sets. These are intended for use on the high-speed Piracus–Athens–Kifissia lines.

Brazil will install 40 main-line locomotives on the Sorocabana Railroad and the Paulista Railroad in the near future. They will be built in Brazil.

The Austrian Railways is electrifying the lines on the Amstten–Selzthal, Klein Peifling–St. Valentin and the Hieflan–Eisenerz routes.

The Roumanian State Railway has electrified its first main from Brasov to Ploesti with the 25-kv 50-cycle system.

The Finnnish State Railways will install 30 electric train sets on the Helsinki–Kirkkonummi and Helsinki–Riihimäki lines which is now being electrified. Average speed will be 31 mph and maximum speed will be 74 mph.

Since the Tokaido line in Japan started operation, several earthquakes have been felt; one with a magnitude of 6.5 and another with a magnitude of 7.9. Protection from damage to trains by earthquake is being studied.

RAPID TRANSIT

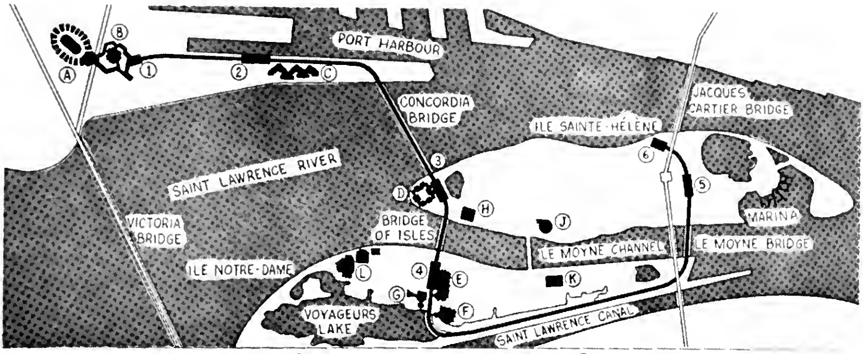
Many of the modern rapid transit systems have installations similar to the electrified railroads. Some of the more important will be discussed here. Speeds, voltages and equipment are frequently similar to railroad suburban usage.

Montreal

A visit to Expo '67, in Montreal, was only possible over North America's first fully automatic rapid transit system. The 3.7 mile route, built expressly for Expo '67, included five stations and three major bridges across the St. Lawrence River. (Fig. 6)

Eight 6-car trains made the continuous runs back and forth on the system. Total passenger carrying capacity was 30,000 persons an hour. Cars for the new Expo Express were supplied by a Canadian builder. Each measures 76 ft long by 10 ft wide, weighs 57,000 lb, and accommodates 200 passengers comfortably. All cars were completely air conditioned for passenger comfort. (Fig. 7)

The 600-v third-rail system is over-running. Electrical energy is collected from an iron rail by means of a shoe mounted on the car truck. (Fig. 8). Anchors to prevent excessive rail creep are located at frequent intervals.



(1) Station - Cité Du Havre
(2) Station - Habitat 67
(3) Station - Ile Verte
(4) Station - Ile Notre-Dame
(5) Station - La Ronde
(6) Station - Service Garage

(A) Automotive Stadium
(B) Expo 67 Entrance
(C) Habitat 67
(D) Place Des Nations
(E) French Pavilion
(F) German Pavilion

(G) British Pavilion
(H) Scandinavian Pavilion
(J) United States Pavilion
(K) Russian Pavilion
(L) Canadian Pavilion

Fig. 6

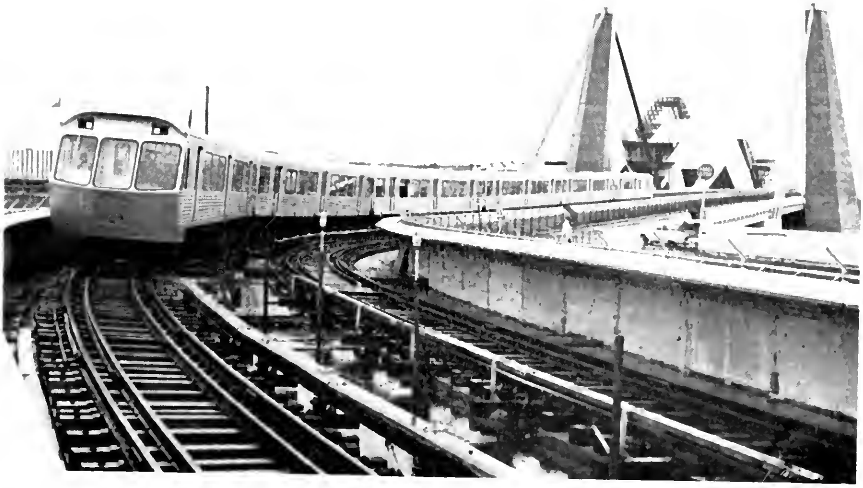


Fig. 7

Fig. 8

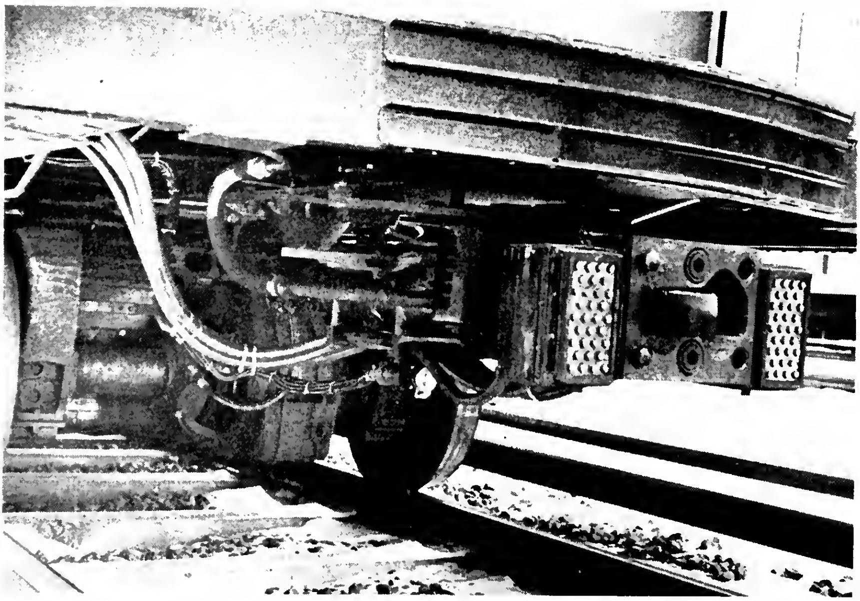


Fig. 9

Electrical, pneumatic and mechanical coupling between cars are accomplished with an automatic coupler. (Fig. 9)

On July 19, the 100 millionth passenger went through a turnstile to board a Montreal Metro subway car. The Montreal Transportation Commission reported that Expo '67 has boosted daily subway riding from 340,000 to 500,000. Metro started operation in the fall of 1966. Metro subway cars operate on rubber tires.

San Francisco

With the total of 48 miles presently under construction, the Bay Area Rapid Transit District plans the beginning of revenue passenger service on the East Bay rapid transit line in mid-1969. The remainder of the planned 75-mile system is scheduled for service the following year.

Original plans called for purchase of 450 transit cars, though a current review seems to indicate a smaller number will be required. Total estimated ridership for the system when completed is approximately 1.1 million passengers per week.

Automatic train control testing is completed. Most of the other problems have been resolved on the test track for the 75-mile regional rapid transit network serving San Francisco, Alameda and Contra Costa Counties. A total of 20 miles is underground including the 4-mile trans-bay tube, 31 miles is aerial construction and 24 miles at grade.

Noteworthy of the progress is the new plant for construction of pre-cast girders and columns. About 2500 heavy girders, up to 100 tons each, are required.

The four-mile transit tunnel under San Francisco Bay consists of twin-barrel tube sections, 48 ft wide and 24 ft high, with two circular bores for the double-track system. These steel fabricated tubes, constructed near the site, are pushed to location then dropped into place in the dredged-out trench in the Bay. Railroad-type couplers join the sections; welding of joints follows.

The distribution system is third rail, 1000 v, d-c.

Cleveland

Construction is under way in Cleveland, with the extension of the rapid transit to Cleveland Hopkins Airport. Studies and feasibility reports detailing the extension of CTS track mileage to the southeast, southwest, northwest, and Heights areas have also been completed.

Cleveland's present transit system measures 15 miles in length. Completion of the airport extension to Puritas Avenue will produce a total of 16¾ miles by January 1, 1968. Twenty new cars will be delivered in the Fall of 1967, scheduled to serve the increasing system needs when the airport extension completes the projected 19-mile system by 1969. Two new substations are now under construction to serve this system.

Catenary overhead similar to that in operation on the existing rapid transit line will be used on this extension. Voltage, 600 a-c (Fig. 10)

New York

New York City Transit Authority operates a total of 721 track miles and carries an average of 26 million riders each week. Officials report considerable modernization and expansion under way, along with a continuing program of updating rolling stock.

In the near future, the Chrystie Street subway will be opened, along with two deep-level express tracks on the 6th Street line connecting the West 4th and 34th

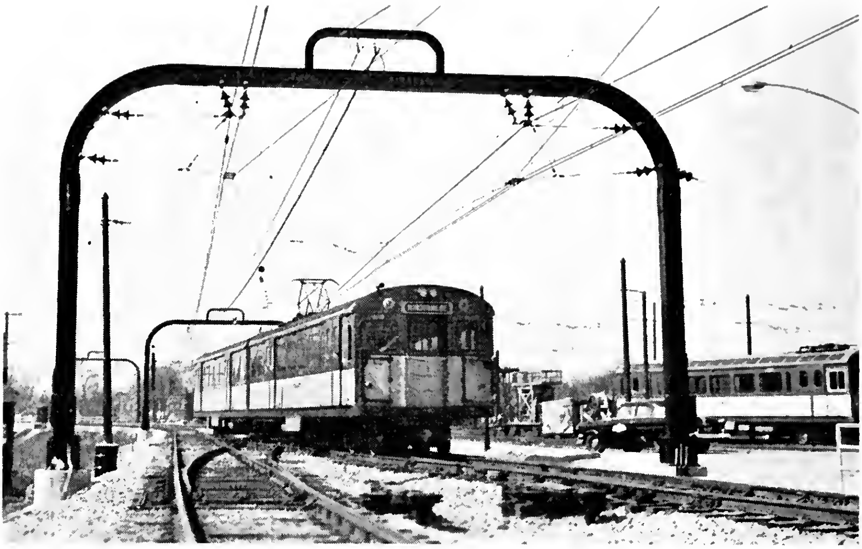


Fig. 10

Street Stations. Two tracks of the 6th Avenue line north from 52nd to 58th Streets are proceeding on schedule and should be completed within one year—including the new station at 57th Street.

Construction is scheduled to begin within the next year on the four-track tunnel under the East River. The line under the river will start at 63rd Street and York Avenue in Manhattan and extend to 41st Avenue and Vernon Boulevard in Queens. Two tracks of this line are scheduled for use by NYCTA trains, with the other two set aside for the Long Island Rail Road. Feeder lines to existing lines in Queens and Manhattan from this tunnel are under study.

Chicago

Rapid transit's on the move in Chicago with system expansion projects underway in almost all the Chicago Transit Authority operations. During 1966, the five-mile, high-speed, Skokie Swift proved its capability and became a successful integral part of the CTA system. For the present, CTA plan to extend the Englewood line about one-half mile, building a new station and increasing park'n'ride facilities for this area in the process. A subway for central Chicago is also in the planning stages. Another project under consideration involves the construction of a passageway between adjacent Chicago & North Western Railway and CTA stations to improve commuter service. Most recently, CTA announced the go-ahead orders for construction of the Kennedy Expressway and Dan Ryan Expressway transit system extensions. As of January 1, 1970, CTA plans to have the Kennedy Expressway and Dan Ryan Expressway systems in service—adding a total of 28 miles of revenue track. CTA also plans the purchase of 108 new cars to serve the new routes upon approval of a grant application for $11.5 million. Chicago's most recent car is shown in Fig. 11.

Fig. 11

Total weekly ridership on the CTA system now averages 9.7 million. A 1.3 percent increase is expected for 1967, over 1966, with additional increases as the new systems enter service.

South Jersey Area

In the South Jersey area, the Delaware River Port Authority reported that contracts now have been let for the estimated $73 million cost of constructing a new 14.5 mile rapid transit line between Philadelphia and Lindenwold, N. J. This new rapid transit route is expected to be completed by mid 1968. Construction is well underway, 75 cars are being built for this system.

Boston

Boston's Massachusetts Bay Transportation Authority reports development of a $369-million Master Plan that will incorporate new construction, additions to existing facilities, and modernization of equipment. MBTA developed this plan to meet the metropolitan area's need for the present and serve as a beginning for increasing service to the growing metropolitan area in the future.

New construction planned on the MBTA system includes five new extensions to the existing system, as well as major improvement of a sixth. MBTA plans a total of 29 miles of new electrified transit routes, plus construction of 25 new stations and modernization of all remaining ones. A capital improvement plan is also in operation for the existing plant.

In regard to systems operation, the MBTA is currently investigating an increase in its distribution voltage from 600 v d-c to 750 v d-c. Also, third-rail investigations are under way which are testing a combination of aluminum with a thin steel veneer and aluminum only as a possible replacement to its present 85-lb steel distribution rail.

Toronto

Plans for the rapid transit system of the Toronto Transit Commission include the 6.26 miles now under construction on the Bloor–Danforth line, plus an additional four-mile extension of the Yonge Street subway approved by the Metropolitan Toronto Council and under consideration by the Ontario Municipal Board. On the Bloor–Danforth line, a 3.49-mile addition will run west from the present Keele Station to Islington Avenue in the Borough of Etobicoke—requiring six new stations. In the east, a 2.77-mile section will link the present Woodbine Station to Warden Avenue and St. Clair in the Borough of Scarborough—including three new stations. The proposed four-mile extension of the Yonge subway will run north from Eglington Station to Sheppard Avenue in the Borough of North York, with construction expected to start sometime in 1968.

Total mileage for the Toronto Transit Commission system is expected to reach 21 by January 1, 1968, a total which will remain constant until 1970.

Los Angeles

A Federal grant of $975,000 has been awarded to the Southern California Rapid Transit Districts for studies of a rapid transit system for the Los Angeles area.

FOREIGN RAPID TRANSIT PROJECTS

Rome is extending the Metropolitan 6¼ miles to Osterea del Curato.

Stockholm is planning a third underground railway to be in operation by 1970.

Construction of the first routes of the Kharkov (Russia) underground railway was started this year.

Mexico City's plans for rapid transit are now ready for a contractor.

Work is well under way on the east–west line of the Brussels Metro. The line will use only rapid transit cars.

From the February 8, 1967 issue of *Business Week* on the Tokyo monorail:

"The only form of public transportation in which the Tokyo passenger can be assured of getting a seat is the sleek and scenic $60-million monorail between Tokyo International Airport at Haneda and Hamamatsu-Cho station in the city 8.2 miles away. Scarcely anyone uses the monorail. Despite its capacity for carrying 71,000 people a day, the average daily load in 1965 was 8,223 passengers, dropping last year to only 7,591.

"Technically, the world's longest commercial straddle-type monorail has done everything it was supposed to do since coming into operation almost two-and-a-half years ago. Completed in September, 1964, Tokyo's monorail has given safe, comfortable service. As intended, the line avoids all ground traffic and skims between terminals in only 15 minutes. Interruptions of the frequent service—every seven minutes from each terminal—are rare. The rolling stock and electronic control system are highly reliable. There are few problems of track maintenance. And yet, the whole project is an economic disaster."

From "Modern Railroads," April, 1967, the flanged wheel on steel rail:

"In the flanged-wheel-on-steel-rail concept, there lies an answer in a tried transport technology that gives every promise of being adaptable to levels of speed and service needed for the next 20 years or longer. This system can use portions of the existing rail network and avoid many high initial costs associated with completely new construction and right-of-way acquisition. The conventional two-rail system offers high capacity, low propulsive force and resistance, sure dependable guidance, low susceptability to weather, privacy in the use of its roadway, and freedom from potential disaster in the event of motive power failure."

FOSSIBILITY OF LESSENING COST OF A DISTRIBUTION SYSTEM

A development for future study is the investigation of the possible application of insulated sodium conductors to the distribution system to lessen its cost. The thought is to utilize an insulated sodium conductor secured to a suitable messenger which in turn would be suspended from conventional 25-kv insulators. The function of the conductor jacket would be only to prevent the access of moisture to the highly reactive sodium and would not be required to provide significant di-electric insulation.

Such a lightweight (and hopefully) low-cost feeder conductor operating at catenary potential would reduce the number of auto-transformers required, and provide economies in the overall consideration.

This subject has been covered in IEEE papers 31-PP-66-443 and 31-PP-66-445.

During the past decade considerable interest has been shown in the linear motor as a means of propulsion for railways and rapid transit. Experiments have been conducted in England.

Propulsion with the linear motor is the result of a reaction between electric current induced in a conducting plate and a traveling magnetic field which induces the current flow.

Among the attractions of using the linear motor for railway traction are:

1. The absence of sliding electrical contacts, rotating electromagnetic parts and gears
2. Freedom from the limitations imposed by adhesion
3. Reduction of the weight of the motor carried on the vehicle because the rotor element is fixed to the track (but, unlike rotating motors, linear motors cannot be geared-up and tend to be heavier than their rotating equivalent on vehicles which operate at low speed)
4. Reduced cost of the electromagnetic part of the motor because of its simple construction
5. Improvement in thermal performance because the reaction plate losses are left behind as the motor proceeds
6. Freedom from restrictions imposed by the peripheral surface speed of rotating motors

Use of a linear motor has corresponding disadvantages, and among them are:

1. Loading gage restrictions
2. Cost of reaction plate
3. Lower efficiency and power factor
4. Need for a lateral guidance system
5. Difficulties on curved track and at points and crossings
6. Three-phase supply with variable voltage and frequency

13F—Develop Methods of Reducing Cost of Electrification Maintenance

C. F. Mulrenan, *Chairman*

One railroad reports use of a new commercial two-component system to protect steel catenary support structures along five miles of line in a heavily industrialized area and adjacent to a toll road.

Atmospheric contaminants and salt spray exposure over a ten-year period had resulted in a considerable amount of corrosion around foundation anchor bolts.

Using highway equipment working from the shoulder of toll road, the railroad's contractor cleaned foundation area and column up to a height of 6 ft with conventional sand-blasting equipment to remove rust, loose scale and paint.

Next, a bituminous compound composed of a special blend of asphalts, petroleum resins, plasticizers, asbestos, mica, and solvent was pumped from drums, atomized and applied to columns with hand-operated spray gun to a film thickness of between 100–130 mils.

The compound affords protection against corrosion, abrasion, sunlight and weathering. While being applied, it follows the contour of the surface exactly, leaving no voids, ridges, or unprotected areas.

Prior to drying, black ceramic granules were sprayed on to the mastic. The granules form an integral part of the coating.

The railroad believes the economical application and expected service life of this system for these catenary support structures is superior to a conventional paint system.

Report on Assignment 15

Relations with Public Utilities

E. M. Hastings, Jr. (chairman), E. L. Abbott, D. W. Aiken, T. F. Jelnick, E. W. Koch, R. F. Pownall, W. M. Haynes, B. A. Ross, R. W. Werts.

Your subcommittee has two assignments and is reporting on both of them.

1. Revised report of Joint Engineering Committee of AAR and EEI on Crossings of Electrical Supply Lines and Facilities of Railroads, is now at the printers and should be ready for distribution about January 1, 1968.

2. The first installation of HVDC Transmission Lines, will be energized for test purposes early in 1969. All companies in the vicinity of the Pacific Northwest, Pacific Southwest inter-tie should be alerted as to the possible effects this may have on their operation. Your committee will continue to study the development of HVDC.

Report of Committee 25—Waterways and Harbors

°**G. R. Collier**, *Chairman*
°**J. C. Fenno**, *Vice Chairman*
°**D. G. Elack**, *Secretary*
°**J. R. Miller**
°**G. E. Anderson**
°**W. D. Phelps**
°**J. F. Piper**
R. L. Pettegrew, Jr.
Shu-t'ien Li
J. M. Bates
G. W. Becker (E)
A. B. Belfield, Jr.
R. L. Bostian, Jr.
W. E. Corbet
C. D. Curran
B. M. Dornblatt
P. P. Dunavant, Jr.
B. Elkind (E)
W. H. Eschwig
J. H. Fitzpatrick
J. E. Foreman, Jr.
C. E. Gilley
H. M. Gresham
J. Gressitt
R. T. Haggerstrom
C. E. Helmle
H. F. Kimball
A. O. Kruse
E. S. Laws
E. C. Lawson
J. P. Layer
R. D. Lowery
L. H. McCurry
F. J. Olsen
A. C. Parker, Jr.
M. S. Patterson
A. L. Sams
D. V. Sartore
H. G. Slaughter
G. A. Stenstrom
C. A. Still
R. A. Ullery
J. D. Vaughan, Jr.
R. F. Weir
S. G. Wintoniak
Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairman, and those designated by asterisks constitute the Engineering Division, AAR, Committee 25.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Current policies, practices and developments dealing with flood control, water conservation, waterways and water navigation projects.
   Progress report, presented as information .... page 254

3. Bibliography relating to benefits and costs of inland waterway projects involving navigation.
   No report.

4. Review of certain principles that may be applied in determining economic justification of inland waterway projects involving navigation.
   No report.

5. Planning, construction and maintenance of rail–water transfer facilities.
   No report.

7. Relative merits and economics of construction materials used in waterfront facilities, collaborating with Committees 7, 8, and 15.
   No report.

The Committee on Waterways and Harbors,
G. R. Collier, *Chairman*.

AREA Bulletin 610, December 1967.

Report on Assignment 2

Current Policies, Practices and Developments Dealing with Flood Control, Water Conservation, Waterways and Water Navigation Projects

G. E. Anderson (chairman, subcommittee), J. M. Bates, A. B. Belfield, J. H. Fitzpatrick, R. V. Gilbert, C. E. Gilley, H. M. Gresham, R. T. Haggerstrom, C. E. Helmle, A. O. Kruse, J. P. Layer, E. S. Laws, R. D. Lowery, L. H. McCurry, A. C. Parker, M. S. Patterson, W. D. Phelps, J. F. Piper, A. L. Sams, C. A. Still, J. D. Vaughan, R. F. Weir.

Your committee submits, for information only, the following report on transportation benefit evaluation procedures which have been adopted for determining the advisability of Federal water resource projects for commercial navigation. The last report of your committee dealing with the policies and practices regarding the authorization of navigation projects was presented in Bulletin 532, November 1956, pages 498–512. Since that report seven additional waterway transportation benefit evaluation procedures have been published and adopted to some degree.

SUMMARY OF ADOPTED PROCEDURES FOR ESTIMATING TRANSPORTATION BENEFITS IN DETERMINING THE ADVISIBILITY OF FEDERAL WATER RESOURCE PROJECTS FOR COMMERCIAL NAVIGATION

INTRODUCTION

The improvement of our Nation's rivers and harbors, as authorized by Congress for commercial navigation, has been carried on by the Corps of Engineers since early in the nineteenth century. The Corps was also given the responsibility by Congress of making the investigations and reports for determination of the advisability of proposed Federal projects for navigation. The project investigation reports which are submitted to Congress must (according to the River & Harbor Act of March 4, 1913) contain "full information regarding the present and prospective commercial importance of the project covered by the report and the benefit to commerce likely to result from any proposed plan of improvement." The Corps of Engineers prior to 1953 also had the sole responsibility for establishing the evaluation procedures to be used in determining the need and economic justification of navigation projects.

In recent years there has been considerable concern regarding economic analysis procedures for evaluating Federal water resource projects. This has led to the development and publication of water resource evaluation standards by two Federal inter-agency committees, the Bureau of the Budget, and the President's Water Resources Council. Each of these evaluation standards presents a procedure for estimating waterway transportation benefits. During the past seven years the Corps of Engineers officially adopted two significantly different navigation benefit evaluation procedures. Congress has recently defined in Public Law 89–670 how the primary direct navigation benefits for a water resource project are to be estimated.

All of the above-mentioned evaluation standards were officially adopted at the time of publication; however, the inter-agency standards were only adopted "as a basis for consideration." One of the procedures developed by the Corps of Engineers

TABLE 1

SOURCE, REFERENCE AND EFFECTIVE DATE OF PROCEDURES ADOPTED FOR ESTIMATING

TRANSPORTATION BENEFITS FROM FEDERAL WATER RESOURCE PROJECTS FOR COMMERCIAL NAVIGATION

	Effective Date
A. PROCEDURES ISSUED BY THE U. S. ARMY CORPS OF ENGINEERS	
1. Annual Report of the Chief of Engineers, for Fiscal Year ended June 30, 1951, Part 1, Volume 3. "Report on the Federal Civil Works Program as Administered by the Corps of Engineers",[a] Inclosure 1 to Appendix E - "Measurement of Benefits of Navigation Projects".	March 27, 1952[b]
2. Orders and Regulations, Part II, Chapter IV, Section 6 - "Surveys For Navigation", Paragraph 4206.23 - "Estimates of Benefits".	Oct. 15, 1952[c]
3. Engineer Manual EM 1120-2-101, "Survey Investigations and Reports - General Procedures", Section V - "Navigation", Paragraph 1-51 "Estimates of Benefits".	June 1956[d]
a. Paragraph 1-51c "Transportation Benefits".	Oct. 17, 1960
b. Paragraph 1-51d "Interim Procedure".	Nov. 20, 1964
4. Engineer Circular EC 1120-2-30, "Waterway Improvement Studies - Navigation Benefits".	Dec. 1, 1966
5. Engineer Circular EC 1120-2-33, "Waterway Improvement Studies - Navigation Benefits".	June 1, 1967
B. PROCEDURES PRESCRIBED BY THE EXECUTIVE OFFICE OF THE PRESIDENT	
1. Bureau of the Budget Circular No. A-47 (Standards and Procedures to be used in reviewing proposed water resources project reports and budget estimates.)	Dec. 31, 1952
2. Senate Document No. 97, 87th Congress, 2d Session, "Policies, Standards and Procedures in the Formulation, Evaluation and Review of Plans for Use and Development of Water and Related Land Resources".	May 15, 1962
C. PROCEDURES PROPOSED BY FEDERAL INTER-AGENCY COMMITTEES	
1. "Proposed Practices for Economic Analysis of River Basin Projects", Report to the Federal Inter-Agency River Basin Committee prepared by the Subcommittee on Benefits and Costs.	May 1950[e]
2. "Proposed Practices for Economic Analysis of River Basin Projects", Report to the Inter-Agency Committee on Water Resources prepared by the Subcommittee on Evaluation Standards.	May 1958[e]
D. PROCEDURE ESTABLISHED BY AN ACT OF CONGRESS	
1. The "Department of Transportation Act" (Public Law 89-670), Section 7 - "Transportation Standards".	Oct. 15, 1966

[a] Submitted to and at the request of the Special Subcommittee to Study Civil Works of the House Committee on Public Works.

[b] Date of submittal. No new navigation project evaluation procedures were presented.

[c] Date of issue for the last edition of this section of Orders and Regulations. (Starting about June 1956 the material in Orders and Regulations was converted to an extensive series of publications consisting of Engineer Regulations, Engineer Manuals, Engineer Pamphlets and Office Memorandums.)

[d] Date of preliminary issue of Engineer Manual for Civil Works, Part CI - "Examinations and Surveys", Chapter 1 - "General Procedures". (The procedure to be used for estimating transportation benefits was not included in Chapter 1. "Navigation Benefits" was to be the subject covered in Chapter 5. When Part CI was later designated as Engineer Manual series EM 1120-2-100, Chapter 1 became Manual EM 1120-2-101 and the proposed Chapter 5 became EM 1120-2-105. Several of the proposed manuals in the EM 1120-2-100 series including EM 1120-2-105 on "Navigation Benefits" have not been issued.)

[e] Date of the report. The proposed practices were adopted for consideration but not for application.

was adopted on an interim basis only. This procedure was subsequently adopted solely for making a supplementary evaluation but was rescinded 44 days after the date of issue. The transportation benefit evaluation procedures adopted to date can be grouped under three basic types; namely, the "current rate" procedure, the "projected rate" procedure, and the "cost of providing the service" procedure.

This summary describes the three basic types of transportation benefit evaluation procedures and presents background information on the publication and adoption of the procedures under each type. A general description of each type is supplemented by quotations from the various procedures of that type. The current procedure is presented in its entirety. Information on the source, reference and effective date of the procedures adopted for estimating transportation benefits is presented in Table 1.

A. "CURRENT RATE" PROCEDURE FOR ESTIMATING TRANSPORTATION BENEFITS

1. Background Information on the Adoption of the Procedure

Prior to recent years the "current rate" procedure was the only procedure which had been adopted for estimating transportation benefits. It has been used ever since Congress first directed the Corps of Engineers to determine the advisability of proposed river and harbor improvements for commercial navigation. The procedure was officially prescribed but presented with few details in the Corps' administrative publication *Orders and Regulations.* A fairly extensive discussion of the procedure was presented in the March 27, 1952, report of the Chief of Engineers on the Federal Civil Works Program as Administered by the Corps of Engineers.

Following a period of nearly 14 years during which the Executive Office of the President had prescribed the "cost of providing the service" procedure, Congress in the "Department of Transportation Act" of 1966 (Public Law 89–670) re-established the "current rate" procedure for estimating the primary direct navigation benefits of a water resource project.

2. Description of the Procedure

The transportation benefits are considered to be the savings in current transportation charges (i.e., rates) to shippers. Both the expected waterway traffic and the unit savings per ton are estimated from a comparison between the current land transportation rates and the rates which would most likely be charged via the proposed waterway. Since most of the inland waterway barge traffic is moved in contract or industry-operated barge service for which there are no published rates, the prospective water-carrier unit charges are usually constucted from a study of the costs of typical barge movements.

A few quotations from references A-1 and A-2 (see Table 1) are presented below, plus the complete detailed procedure given in reference A-4, which constitutes the current procedure to be followed by the Corps of Engineers. The transportation investment standards for navigation benefits of a water-resource project established in Public Law 89–670 are presented in section 5 of the procedure in reference A-4.

a. Quotations from *Annual Report of the Chief of Engineers,* 1951, Part 1, Vol. 3:

"Estimates of navigation benefits are arrived at by comparing the transportation charges now paid by, or transportation costs now available to, shippers via existing land or water carriers against the probable transportation charges to shippers via the prospective waterway. Usually most of the prospective traffic is bulk freight which does not travel by common-carrier water line but rather by contract or by industry-operated barge service, for which there are no published rates. Prospective water-carrier unit charges are therefore usually built up from studies of going barge-line and river-terminal operations, and from exhibits filed by water carriers in the various I.C.C. barge- and rail-rate cases."

"While there are usually no published water rates applying to the prospective movements, the above tests lead to the construction of hypothetical systems of barge-lot rates which carriers would find remunerative under the operating conditions to be provided by the respective proposed improvements. These rates are compared with the rates under which the water-adapted freight is actually moving or able to move. The unit savings thus derived for the various commodities are applied to the tonnages in the final estimate of prospective freight to determine the probable savings to the shipping public that will result from provision of the improvement."

"The apparent loss of traffic by existing carriers from diversion of traffic to a waterway is not applied as a reduction of benefit. The Corps of Engineers considers that there is an over-all economic gain to the nation when transportation is made available to the public at lower cost and that, as has happened in most such cases, benefits to overland carriers from feeder and transfer traffic developing as a result of the waterway will in the long run offset losses by overland carriers of shipments suited to water movement."

b. Quotations from *Orders and Regulations*, Paragraph 4206.23.

"In the final analysis, the probable transportation charges by water should be compared with the lowest present charges actually paid by, or available to, the shipping public. On the assumption that the present transportation charges provide a reasonable income on the necessary capital investment and operating outlay of existing carriers, the estimated charges by water should likewise provide a reasonable income on the necessary capital investment and operating outlay of the water carriers."

"If the proposed improvement will develop new waterway movements that exclude increased traffic to existing waterways, the estimated saving for the complete water movement will be included as a benefit, and no part of such saving should be deducted on the theory that it should be assigned to the connecting waterway. On the other hand, when a proposed improvement will result from the extension of waterway movements already developed, only the savings which result from the extension of the movements would be included as a benefit, and no part of the saving already being realized by movement on the existing waterway will be included as a benefit for the new improvement."

c. Complete Procedure Presented in *Engineer Circular* EC 1120–2–30:

SURVEY INVESTIGATIONS AND REPORTS

Waterway Improvement Studies—Navigation Benefits

1) Addressees: Division Engineers except Mediterranean; District Engineers except Canaveral, Gulf, Far East, and Okinawa; Resident Member, Board of Engineers for Rivers and Harbors.

2) Purpose: This Circular sets forth the bases for the rates and charges for use in evaluating the savings to shippers from waterway traffic that would move by other means in the absence of the waterway. Also, it

explains the bases for the evaluation of the navigation benefits from waterway induced traffic which would not move in the absence of the improved waterway. The Circular has reference only to the subject matter in part 1–51 of Section V of EM 1120–2–101; other parts of this Section are unaffected.

3) Scope: The guidance herein is applicable in pre-authorization navigation studies and in restudies of the economic justification of authorized navigation projects.

4) References:
   a) EM 1120–2–101, Section V, "Subject Matter of Navigation Studies and Reports."
   b) EC 1120–2–28, dated 29 August 1966.
   c) Department of Transportation Act of 1966 (Public Law 89–670).

5) Definition of navigation benefits in Public Law 89–670: The Department of Transportation Act of 1966 (Public Law 89–670) in Section 7 (a) provides: "The standards and criteria for economic evaluation of water resource projects shall be developed by the Water Resources Council established by Public Law 89–80. For the purposes of such standards and criteria, the primary direct navigation benefits of a water resource project are defined as the product of the savings to shippers using the waterway and the estimated traffic that would use the waterway; where the savings to shippers shall be construed to mean the difence between (a) the freight rates or charges prevailing at the time of the study for the movement by the alternative means and (b) those which would be charged on the proposed waterway; and where the estimate of traffic that would use the waterway will be based on such freight rates, taking into account projections of the economic growth of the area."

6) Basis for evaluation: Pursuant to PL 89–670 each Corps navigation study will include on estimate of savings to shippers via the considered waterway, measured as the product of estimated waterway traffic and estimated unit savings to shippers in the movement of that traffic measured as the difference between rates they actually are paying for transportation at the time of the study and rates they probably would pay for transportation via the improved waterway. Where rates prevailing in the area at the time of the study are not appropriate for the type and volume of the traffic considered potential to the waterway, applicable rates will be constructed as provided herein below.

7) Categories of waterway traffic: For purposes of estimating savings to shippers, waterway traffic estimates will be made on an origin to destination basis, subdivided into the following categories:
   a) Commodities moving in the study area by various modes in barge load volumes at the time of the study.
   b) Commodities not moving in the study area in barge load volumes at the time of the study but which in the absence of waterway improvement may be expected to move in such volumes sometime during the life of the considered waterway as part of the normal economic growth of the study area.

c) Commodities which may be expected to move in barge load volumes in the future only if the waterway is improved (i.e., waterway induced traffic).

With respect to induced waterway effects it may be necessary to identify sub-categories of the above, for example, where waterway improvement would advance the date of first movement to be expected under category 7b or retard possible decline in traffic under category 7a.

8) Choice of alternative modes of transportation: The alternative modes of transportation to be used in estimating savings to shippers are those actually in use at the time of study for the volume movement of traffic or, where there are no such existing movements, those that would most likely be used for such movements. In the latter case, alternative modes will be chosen on the basis of minimum rates to shippers contructed as outlined below, with special consideration being given to category 7c traffic as subsequently discussed. The competitive effects of authorized waterways, not yet constructed, should be considered in the economic analysis.

9) Rates to shippers via alternative modes: For purposes of estimating savings to shippers the following rates for transportation via alternative modes will be used:

a) Category 7a traffic: Rates shippers actually are paying at the time of study.

b) Category 7b traffic: Constructed rates based on those existing elsewhere at the time of the study which are most nearly applicable to the type and volume of expected waterway traffic, excluding those existing rates which are influenced by waterway competition, except that where existing rates in the study area for volume movements are available for portions of an alternative mode movement these will be used to the extent appropriate in construction of origin to destination rates. Rates constructed on the latter basis (i.e., part existing and part constructed) will be used when they are smaller than constructed through (i.e., full origin to destination) rates.

c) Category 7c traffic: Traffic in this category is not expected to move by alternative modes and is discussed in paragraph 13, following.

10) Rates to shippers via improved waterway: There will be no existing rates for waterway movement over the improved waterway. Accordingly, waterway rates for traffic categories 7a, 7b, and 7c will be based on water-carrier rates or charges existing elsewhere at the time of the study which are most nearly applicable to the type and volume of expected traffic on the improved waterway. For this purpose fullest practicable use will be made of water-carrier tariffs filed with the Interstate Commerce Commission, State regulatory agencies, and of data secured from other recognized transportation authorities, including barge-line operators. Rates and charges based on these sources may be applied directly to the waterway under study on a ton-mile basis or by establishing the relationship between prevailing rates and the estimated cost of movement (including normal return on investment), and in turn applying this relationship to the estimated cost of movement on the considered waterway. Where there are no comparable movements, rates

will be constructed on the basis of barge costs reflecting the nature and volume of the waterway traffic.

11) Where the movement involves a haul to and/or from the improved waterway, the rate to shippers with the waterway improvement will be constructed on the basis of a composite of waterway and associated movements, taking into account the guidance given in paragraph 9b for the non-waterway components.

12) Estimated waterway traffic: Traffic in categories 7a and 7b for which the difference in rates specified in paragraph 6, above, are positive will be considered as estimated waterway traffic for purposes of estimating savings to shippers.

13) Evaluation of category 7c traffic: By definition this is traffic that would move on the improved waterway but would not move in the study area in the absence of the waterway and on which there would be no savings to shippers as defined above. For any such traffic a different basis of evaluation will therefore be required. Two conditions will need to be considered:

a) The movement of commodities over the improved waterway which would be supplied to the same markets from sources outside the study area in the absence of the waterway improvement.

b) The movement of commodities over the improved waterway which, because of the consequent lower delivered price, would comprise a net addition to the total quantities of these commodities used and consumed.

The determination of waterway traffic for each category will require an analysis of the quantities of these commodities that would be marketable from the study area with the waterway both in terms of total demands and competitive sources of supply.

For waterway traffic consisting of commodities which would be supplied from sources outside the study area in the absence of the waterway improvement, the navigation benefits will be measured by the difference in the total delivered cost of the commodities from sources within the study area and the total delivered cost from the alternative sources of supply in the absence of the improved waterway.

For that portion of the waterway traffic consisting of commodities which would constitute a net addition to the total amounts used or consumed the navigation benefits will be assumed equal to the product of the waterway traffic times one-half* of the difference between the constructed alternative rates (9b above) and the constructed waterway rates (10 above).

14) Associated transportation charges: To the fullest practicable extent, freight rates and charges for the movement of commodities by all alter-

*This rule-of-thumb approach assumes that rates lower than the constructed alternative rates would be required to move this traffic. Some part of the total induced traffic would move at a rate slightly below the constructed rate. Additional increments of traffic would move only at rates further reduced. The last increment would move only at the waterway rate. In the absence of evidence to the contrary, it will be assumed that the induced traffic would be evenly distributed between the alternative constructed rate and the waterway rate and that the average unit benefit is equal therefore to one-half the difference between these two rates. This approach is in accord with the procedure stated on Page 41 of the "Green Book" (reference C-2 in Table I).

native modes of transportation and via the considered waterway improvement will include applicable charges for such services as transfer, handling, switching, and storage as may be required to effect the full transportation service from origin to destination.

15) The main body of each navigation study report will show clearly the rates used in the evaluation and explain their derivation.

16) Questions arising from the application of the procedures discussed above in specific studies should be brought to the attention of OCE, Attn: ENGCW-PE for resolution.

B. "COST OF PROVIDING THE SERVICE" PROCEDURE FOR ESTIMATING TRANSPORTATION BENEFITS

1. Background Information on the Adoption of the Procedure

The procedure was proposed in both the original May 1950 report and the revised May 1958 report on "Proposed Practices for Economic Analysis of River Basin Projects" prepared by the Federal inter-agency committees dealing with river basin water resources. Both reports were adopted "as a basis for consideration" by the participating agencies, including the Corps of Engineers.

The procedure was officially prescribed by the Executive Office of the President in Bureau of the Budget Circular No. A-47 which required that all reports submitted by the Executive Department after July 1, 1953 "must conform to the requirements of this circular." Circular A-47 was adopted for application by the Corps of Engineers with the issuance, by order of the Chief of Engineers, of multiple letter ENGKW 800.12 dated January 22, 1953, which stated:

"Effective immediately reports and budget estimates on Corps of Engineers civil works projects to be reviewed by the Bureau of the Budget will be subject to the standards and procedures outlined in the inclosed circular."

"Appropriate changes will be made in *Orders and Regulations*."

In lieu of revising the section on estimates of transportation benefits in *Orders and Regulations*, the Corps of Engineers issued the "cost of providing the service" procedure as part of change No. 11, dated October 17, 1960, to *Engineer Manual* EM 1120-2-101.

The procedure was specified in Senate Document No. 97, 87th Congress, which was approved on May 15, 1962, by President Kennedy for application by the Bureau of the Budget and the Federal agencies which would comprise the Water Resources Council under the proposed Water Resources Planning Act. In Connection with this action the Bureau of the Budget rescinded Circular No. A-47.

Senate Document No. 97 was adopted for application by the Corps of Engineers with the issuance of multiple letter ENGCW-PD for the Chief of Engineers dated June 15, 1962 which stated:

"The policies, standards, and procedures specified in the statement * * * are effective immediately in Corps of Engineers' activities involving the formulation, evaluation, and review of plans for use and development of water and related land resources."

The policies, standards, and procedures presented in Senate Document No. 97 were developed in response to the President's memorandum of October 6, 1961, by the Secretaries (of the Departments of the Army; Agriculture; Health, Education, and Welfare; and Interior) who would comprise the Water Resources Council under the Water Resources Planning Act proposed by the President. The Water Resources

Council, which was subsequently established by the Water Resources Planning Act of July 22, 1965, (Public Law 89–80) and which, according to this act, shall establish the standards and criteria for economic evaluation of water resource projects, adopted the standards and criteria presented in Senate Document No. 97 without change.

The procedure was replaced by the "current rate" procedure with the passage of the "Department of Transportation Act" of 1966 (Public Law 89–670).

2. Description of the Procedure

The transportation benefits are considered to be the savings in the cost of providing equivalent transportation service. The cost of providing the service is considered to be the long term incremental (i.e., added) costs (other than project costs) which in the absence of the traffic would be avoided. Both the amount of prospective water-borne commerce and the unit savings in transportation costs are determined by a comparison of the incremental costs for the waterway and for the alternative means of transportation.

The procedure is presented in references A-4, B-1, B-2, C-1 and C-2 (see Table 1). Quotations are presented below from each reference except C-1 which is almost identical to C-2 regarding navigation benefit evaluation procedures.

a. Quotations from Bureau of the Budget Circular No. A-47:

"Benefits to be included in evaluation." * * * "In the case of navigation projects other than harbor improvements, the transportation savings resulting from: (1) The differential between expected costs of movement by non-water transport and expected costs of movement by water transport for those commodities which will be carried by land transport if the project is not built, but which will move by water if the project is built."

"Costs to be included in evaluation." * * * "Such an evaluation shall also include a statement of economic costs expected to be induced by the program or project, such as the costs of: * * * d. Business losses, such as disruption of trade or diversion of waterborne traffic from existing ports or channels."

b. Quotation from the Inter-Agency Committee on Water Resources Report on "Proposed Practices for Economic Analysis of River Basin Projects":

"The benefits of a navigable waterway are the value of the transportation services provided after allowance for the cost of the associated resources required to make the service available. Such values of transportation service may be derived in terms of the cost of the most likely alternative means of providing the service in the absence of the project. Thus, the project may be credited with the value of the transportation service that will be provided less associated costs (all costs other than project costs) necessary to provide the service. From a public viewpoint, a navigation project will be considered economically desirable if it results in provision of needed transportation service at a lesser total expenditure for goods and services than may be expected to be necessary to provide equivalent service in the absence of the project. On this basis, transportation costs rather than transportation rates (i.e., costs to shippers) should be used for measuring benefits whenever possible."

"In considering the justified investment for project navigation, account must also be taken of the cost of equivalent transportation services by the most economical alternative means, with interest and taxes for both computed on a comparable basis."

"In estimating associated costs, which include investment and operating costs for vessels, terminal facilities, etc., allowance should be made for any increase in costs to shippers and receivers of cargo due to differences in the character of transportation service by waterway as compared with alternative means. For example, the greater time in transit or storage and different handling requirements may be factors requiring such allowance."

"Where it may be necessary to use rates charged for transportation service as the measure of cost of transportation by an alternative means, the benefit credited to the project should be adjusted for any reduction in net income by transportation services from which traffic is diverted."

c. Quotations from *Engineer Manual* EM 1120–2–101, Par. 1–51c, Oct. 17, 1960:

"Transportation benefits. The principal transportation benefits of navigation improvements are the savings in the cost of moving commodities which in the absence of the improvement would move by other means from the same or other sources. These are the savings in costs to whomsoever they may accrue, made possible by the improvement. In computing these savings it will be assumed that, in the absence of the waterway improvement, use would be made of the alternative means that could move the traffic at least cost. In selecting the least costly alternative means, consideration will be given to all transportation media or combinations thereof, existing and reasonably potential, that are suitable for the purpose."

1) "Basis for Estimating Savings in Transportation Costs: The costs to be compared in the analysis are all of the incremental (added) costs in the waterway improvement and in the least costly alternative means that would be required in moving the estimated traffic by the two media. For both the waterway and the alternative means, the base from which costs are measured is the current condition. No cost should be included in the analysis for existing facilities, that is, "sunk" costs. For example, if the contemplated improvement is the deepening of an existing waterway none of the original cost of constructing the waterway should be included since this cost cannot be affected by the decision whether or not to make the improvement. Likewise, if the increased traffic could move by existing rail facilities without requiring additional right-of-way, roadbed, general plant, etc., no cost for these items should be included in the cost comparison. If, however, replacement of or additions to any such items or increased operation and maintenance will be required over the period of the economic life of the project to accommodate the estimated increase in traffic in the waterway or the alternative means, such costs should be included. This will necessitate an estimate of the growth in traffic over the evaluation period and a comparison with the capacity of existing facilities to accommodate this growth."

2) "Relationship of Costs to Rates: The costs of movement of commodities by alternative means may not be as readily available as are the rates published by carriers for such movements. Such rates may or may not reflect actual cost involved. Thus, analyses of transportation savings based upon such rates may not give a true measure of the value of a waterway improvement. Where it is not possible to obtain actual cost figures for movement by alternative means, published rates may be used when, in the opinion of reporting officers, they represent costs. Where there is

strong possibility that the rates for movements under consideration do not approximate costs, the best estimates of overland carrier costs will be used in the analysis. Thus, in any case where rates are used as a basis for computing the cost of movement by alternative means, the relationship of rates to costs must be established."

d. Quotations from Senate Document No. 97, 87th Congress, 2d Sess., May 1962:

"Navigation benefits: The value of services provided after allowance for the cost of the associated resources required to make the service available. For commodities that would move in the absence of the project, the benefit is measured by the saving as a result of the project in the cost of providing the transportation service."

"Induced costs: All uncompensated adverse effects caused by the construction and operation of a program or project whether tangible or intangible."

"Induced costs may be accounted for either by addition to project economic costs or deduction from primary benefits."

C. "PROJECTED RATE" PROCEDURE FOR ESTIMATING TRANSPORTATION BENEFITS

1. Background Information on the Adoption of the Procedure

The procedure was proposed by the Pittsburgh District Engineer, U. S. Army Corps of Engineers, and used in his survey report of January 1965 on the Lake Erie–Ohio River Canal project. This report states the current rate procedure was considered inadequate because it "would not reflect the technological advances and subsequent rate reductions made by railroads through train-load movements of high-volume dry-bulk commodities." The incremental cost of providing the service procedure was rejected because "it is clear that the railroads could not establish rates that would approach the long-term incremental costs furnished" based on a comparison of these incremental costs and the prevailing out-of-pocket costs for these railroads as defined and determined by the Interstate Commerce Commission. The Pittsburgh District Engineer also stated that the long-term incremental cost method is "considered not completely valid since it fails to recognize all of the cost factors bearing on tariff rates and savings." "These long-term incremental costs associated with the operation (costs that would not be incurred if the train were not operated), are lower than Interstate Commerce Commission out-of-pocket costs as they make no provision for track overhead, and return on investment in road property."

The procedure was adopted for application by the Corps of Engineers as an interim procedure with the issuance, by order of the Chief of Engineers, of multiple letter ENGCW-PE dated Nov. 20, 1964 which stated:

"The Chief of Engineers has decided that, pending the availability of acceptable data for consistent application of the cost basis in the evaluation of waterway transportation benefits, the procedures set forth herein will be applied immediately at all levels in evaluating the navigation benefits from the movement of traffic that would move by alternative means in the absence of the waterway improvement."

"These instructions will be incorporated in an early revision of EM 1120–2–101."

The interim procedure was added as Paragraph 1–51d and included with the list of changes to EM 1120–2–101 identified as Change No. 16 dated October 12, 1964.

Use of the procedure was terminated by a directive from the Bureau of the Budget dated August 24, 1966 which stated:

"the Chief of Engineers will submit to the Congress reports on navigation projects as developed on the basis of instructions in effect prior to November 20, 1964. The interim procedure promulgated by the Chief of Engineers on November 20, 1964 will be discontinued * * *."

A similar procedure (to the extent that it also uses the reduced land transportation rates obtainable through train-load movements rather than current land transportation rates in the area) was adopted for application as a supplementary procedure by the Corps of Engineers with the issuance of *Engineer Circular* EC 1120–2–33, for the Chief Engineers, dated June 1, 1967 which stated:

"The purpose of this Circular is to define a requirement for making and reporting supplementary analyses which will state an approximation of the navigation benefits accruing to the national income account through the improvement of waterways, using rates in effect within or outside the study area for large volume movements reflecting modern technology and relevant incentives. However, recommendations of the reporting Officers are to be based upon the criteria stated in Section 7 (a) of the Department of Transportation Act of 1966."

The Office of the Chief of Engineers by letter of July 14, 1967 rescinded *Engineer Circular* EC 1120–2–33 effective immediately.

2. Description of the Procedure

The transportation benefits are considered to be the savings in the projected (i.e., future) transportation charges (i.e., rates) to shippers. The expected waterway traffic is estimated from a comparison of the land transportation and waterway tranosportation rates likely to prevail in the future with the waterway improvement. The unit transportation savings credited to the waterway improvement is determined from a comparison between the projected land transportation rates in the absence of the waterway improvement and the rates most likely to prevail via the waterway.

The procedure is presented in references A-3-b and A-5 and quotations from each are presented below.

a. Quotations from *Engineer Manual* EM 1120–2–101, Change No. 16, Par. 1–51d:

1) "Definitions:

a) Projected 'water-compelled' rates: These are the rates considered likely to prevail in the future with the waterway improvement.

b) Projected 'non-water-compelled' rates: These are the rates considered likely to prevail in the future in the absence of the waterway improvement.

2) "Determination of waterway traffic: The traffic that would be expected to move over a considered improved waterway will be estimated on the basis of projected 'water-compelled' rates with consideration of all data and factors that are likely to modify current rates to take account of the competitive situation anticipated with the waterway in being, and foreseeable technological developments applicable to the several transport media.

3) "Unit savings: Estimates of unit transportation savings attributable to the waterway improvement will be determined on the basis of the projected 'non-water-compelled' rates, with consideration of all pertinent data and factors, including the competitive situation anticipated in the

absence of the waterway improvement, current rates, and foreseeable technological developments applicable to the several transport media.

4) "Other rates and charges: The rates and charges for waterway movements and for alternative movements will consist of all of the costs to shippers for complete and comparable movements from point of origin to destination and will include, as applicable, loading and unloading, line-haul, switching, stockpiling and terminal services.

5) "Transportation benefits: The transportation benefits of a considered waterway improvement, for the movement of traffic that would move by other means in the absence of the waterway, will be derived by applying to the traffic movements estimated as in 2), above, the unit savings estimated as in 3), above. These benefits will be used in project justification and in computing the benefit-cost ratio.

6) "Savings based on current rates: In addition to the derivation of benefits based on projected rates, reports will include an estimate of savings obtained by applying unit savings based on the rates prevailing at the time of the study to the waterway traffic estimated to move on the basis of such rates. The savings thus estimated should be further adjusted for any differences expected in transfer and terminal charges. This estimate is for information only, and the decision on project justification will be based on the analysis as stated in 5), above."

b. Quotation from *Engineer Circular* EC 1120–2–33, June 1, 1967:

"The supplementary analysis will use prevailing rates wherever in effect which reflect technological improvements, modern operating methods, such as self-unloading barges, container-barge operations and unit trains and, where applicable, the use of incentive rates for large volume, e.g., barge load, multiple barge, single car, multiple car, and trainload movements."

Report of Committee 28—Clearances

°**J. A. Crawford,**
Chairman
°**M. E. Vosseller,**
Vice Chairman
°**R. L. Williams,**
Secretary

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W. S. Tustin
M. Van Kuiken
J. W. Wallenius
E. W. Wotipka
Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 28.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress, submitted as information .... page 268
2. Compilation of the railroad clearance requirements of the various states.
   Report and chart, submitted as information .... page 275
3. New methods and electronic devices for recording measurements of clearances of structures along right-of-way and overall dimensions of cars and loads in yards and at interchange points, looking to the possible use of a computer program for routing high and wide loads.
   Progress report, submitted as information .... page 275
4. A study of the restrictions that the clearance personnel in the engineering departments of the various railroads furnish their transportation and/or operating departments for the handling of loads of excessive sizes and weights.
   No report. A questionnaire concerning this subject was sent to all members of the committee. After receipt of the replies, it became evident that a broader representation of railroads is both desirable and necessary; therefore the questionnaire will be sent to the appropriate officer within the engineering departments of selected additional roads.
5. Clearance allowances to provide for vertical and horizontal movements of equipment due to lateral play, wear and spring deflection, collaborating as necessary or desirable with the Mechanical Division, AAR.

No report. The data obtained in the April 1965 tests runs using high-cube box cars have not yet been released. No further tests of this or similar nature were made during the past year.

6. Feasibility of formulating a more complete method, for use of Transportation Departments, in reporting loads of excessive dimensions to minimize necessity for requesting additional information, collaborating as necessary or desirable with the Mechanical Division, AAR.
Status report, submitted as information .... page 276

THE COMMITTEE ON CLEARANCES,
J. A. CRAWFORD, *Chairman.*

AREA Bulletin 610, December 1967.

Report on Assignment 1

Revision of Manual

S. M. DAHL (chairman, subcommittee), B. BRISTOW, J. A. CRAWFORD, R. T. DEDOW, J. E. FANNING, G. P. FOSQUE, A. R. HARRIS, W. F. HART, O. H. JENSEN, E. C. LAWSON, B. W. MCCURDY, E. E. MILLS, J. R. MOORE, R. C. RANKIN, A. G. RICHMOND, E. C. SMITH, M. VAN KUIKEN, M. E. VOSSELLER, R. L. WILLIAMS.

Your committee has reviewed the Special Notes and the Diagrams, Parts 1 and 2, respectively, in Chapter 28, with particular regard to the effect of the increased size, and the new types, of cars which have come into use.

The following Special Notes and Diagrams have been developed as a result of this review, and your committee plans to recommend them next year for adoption and publication in the Manual in lieu of present Parts 1 and 2.

This progress report is submitted as information and for comments by the membership of the Association.

SPECIAL NOTES

1. The clearances shown are for tangent track and new construction. Clearances for reconstruction work or for alteration are dependent on existing physical conditions and, where reasonably possible, should be improved to meet the requirements for new construction.

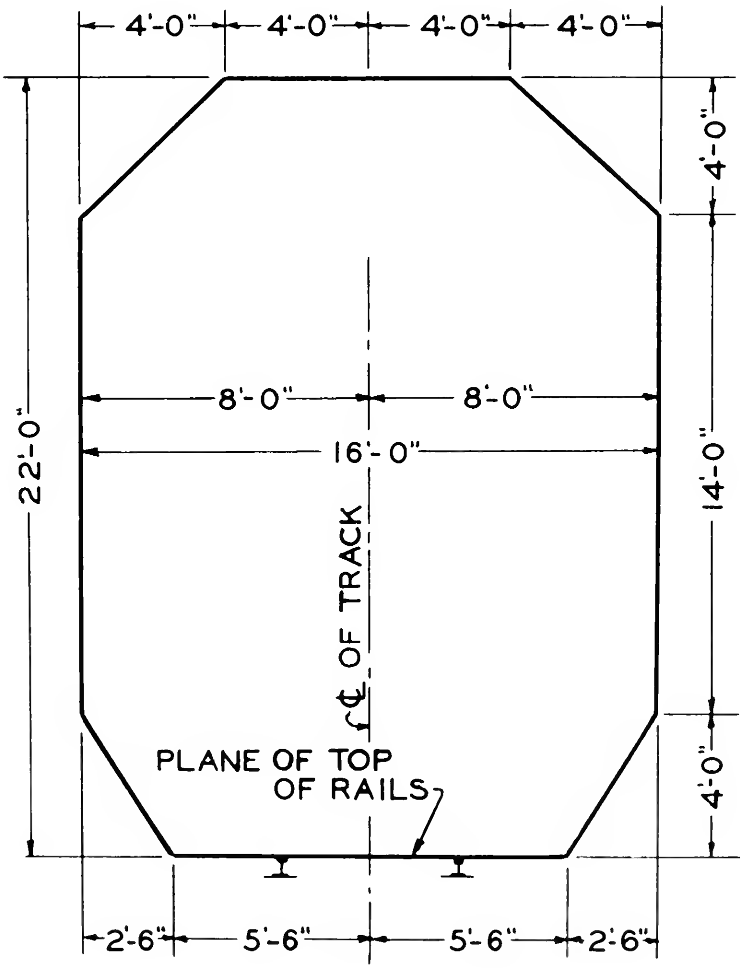
2. On curved track, the lateral clearances shall be increased 1 in per deg of curvature, with a maximum increase of 18 in. When the fixed obstruction is on tangent track but the track is curved within 80 ft of the obstruction, the lateral clearances shall be increased as follows:

Distance from Obstruction to Curved Track (in Feet)	*Increase Per Degree of Curvature (in Inches)*
0–20	1
21–40	¾
41–60	½
61–80	¼

3. The superelevation of the outer rail shall be in accordance with the recommended practice of the AREA.

4. Legal requirements to govern when in conflict with the dimensions shown.

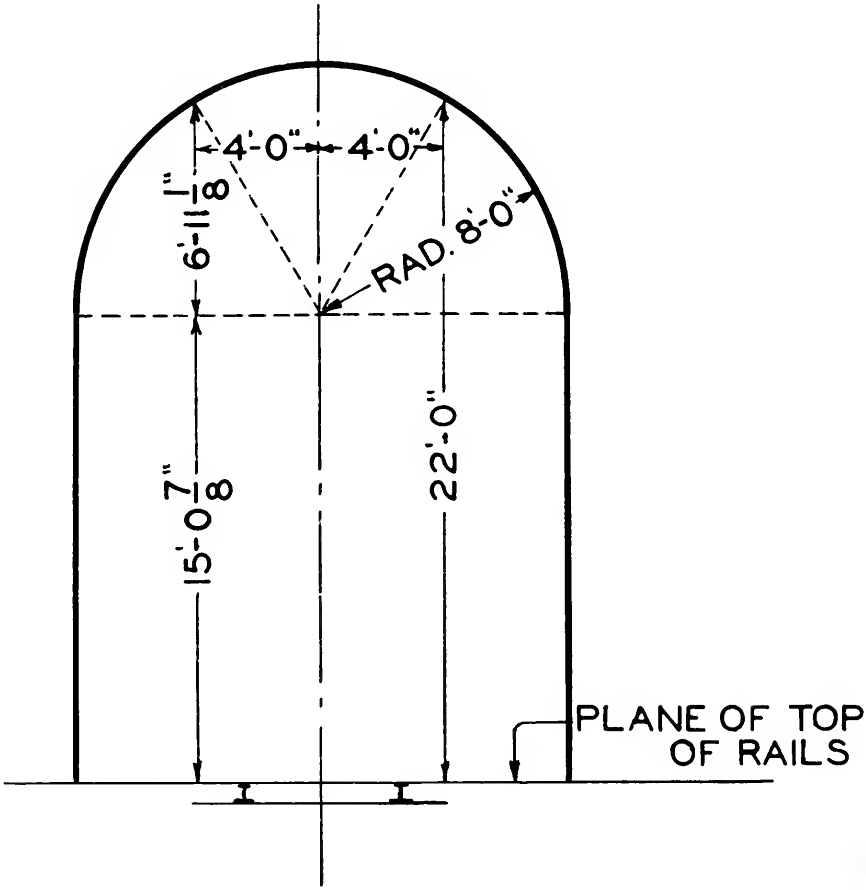
CLEARANCE DIAGRAM FOR RAILWAY BRIDGES AND TURNTABLES



TRACK ON TANGENT

FIG. 1

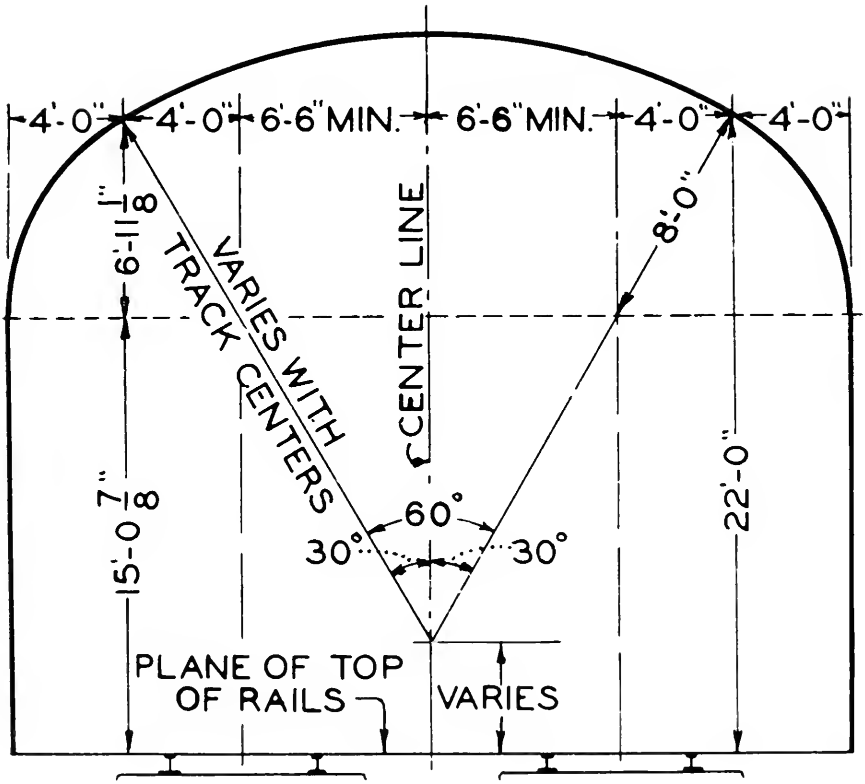
CLEARANCE DIAGRAM FOR SINGLE-TRACK TUNNEL



TRACK ON TANGENT

FIG. 2

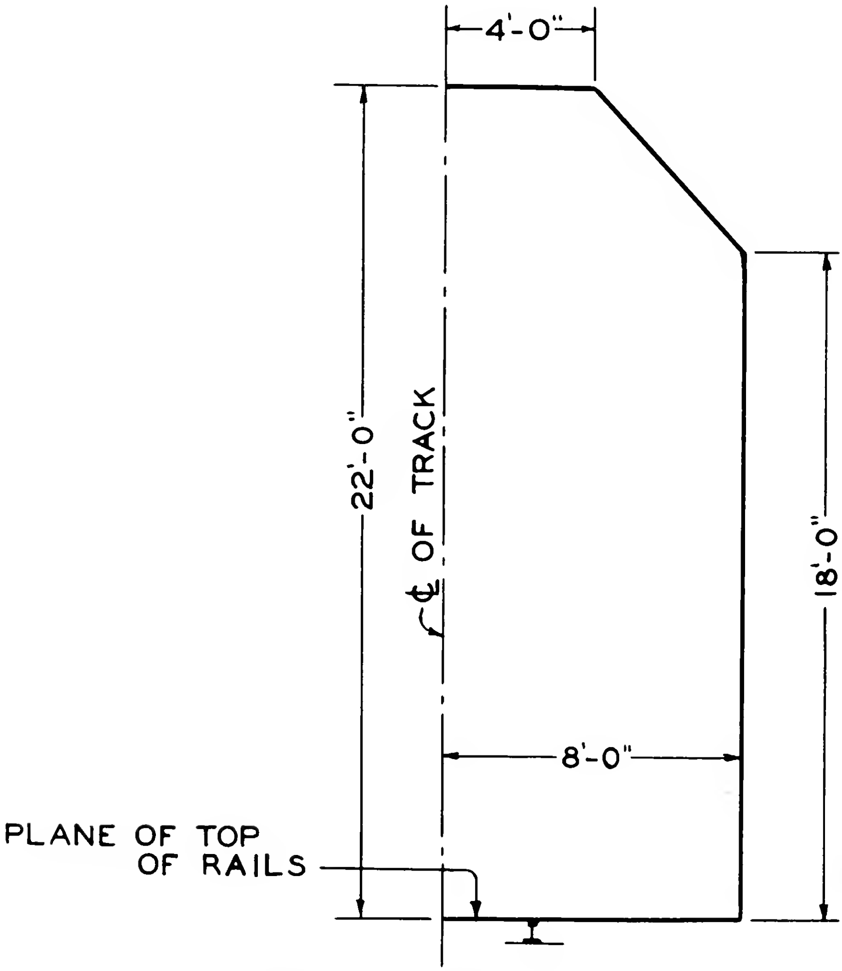
CLEARANCE DIAGRAM FOR
DOUBLE-TRACK TUNNEL



TRACK ON TANGENT

FIG. 3

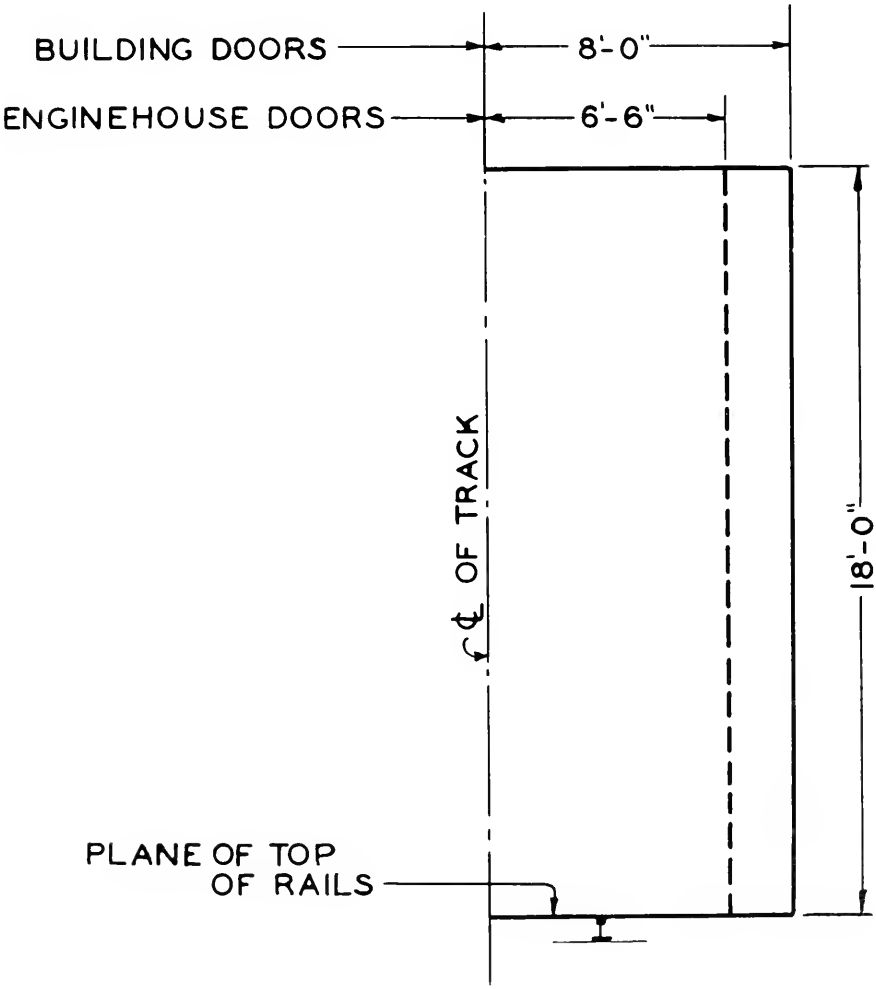
CLEARANCE DIAGRAM FOR STRUCTURES (OTHER THAN PLATFORMS) ADJACENT TO INDUSTRIAL SIDE TRACKS



TRACK ON TANGENT

FIG. 4

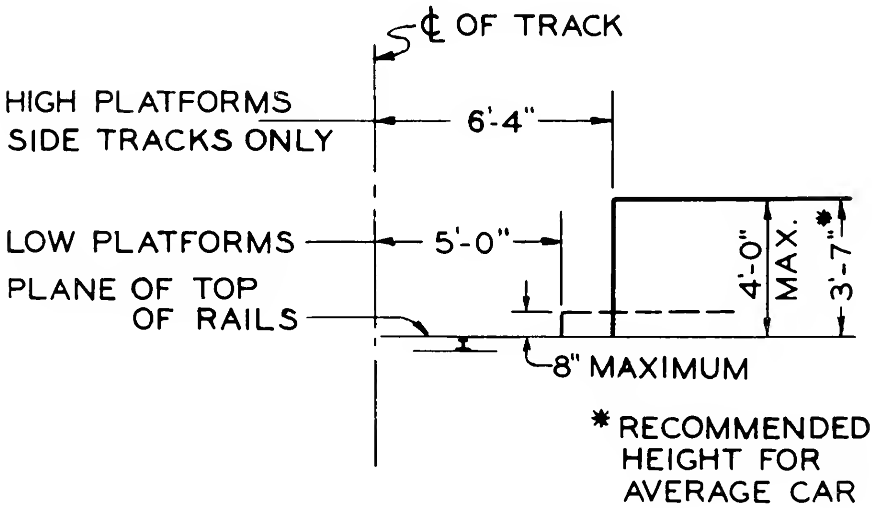
CLEARANCE DIAGRAM FOR BUILDING DOORS



TRACK ON TANGENT

FIG. 5

CLEARANCE DIAGRAM FOR PLATFORMS

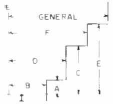


TRACK ON TANGENT

THE 6'4" DIMENSION WILL ACCOMMODATE CARS WITH EITHER FLUSH SLIDING DOORS OR PLUG DOORS. CARS WITH HINGED DOUBLE DOORS REQUIRE FULL CLEARANCE OF 8' 0". WHERE 6' 4" PLATFORM IS USED, FULL CLEARANCE SHOULD BE PROVIDED ON OPPOSITE SIDE, EXCEPT INSIDE BUILDINGS.

FIG. 6

LEGAL CLEARANCE REQUIREMENTS



	REGULATION REFERENCE		TRACK CENTERS: MAIN TRACK	ANY TWO SUBSIDIARY TRACKS	ADJACENT SUBSIDIARY TRACK TO ANY MAIN TRACK	LADDER TRACK ADJACENT TO ANY PARALLEL TRACK	TWO ADJACENT PARALLEL LADDER TRACKS	LEAD, REPAIR AND CABOOSE TRACKS	TEAM TRACK - IN PAIRS	UNLOADING TRACK AT PLATFORMS	VERTICAL: GENERAL	THRU BRIDGE	HIGHWAY BRIDGE	TUNNELS	BUILDING DOORS	IN BUILDING	HORIZONTAL: GENERAL	THRU BRIDGE	HIGHWAY BRIDGES	TUNNEL	BUILDING DOORS	IN BUILDINGS	PLATFORMS: GENERAL A	B	C	D	E	F	HIGH	SIGNALS: LOW, BETWEEN TRACKS: HEIGHT	CLEARANCE	SWITCH BOXES, ETC: HEIGHT	CLEARANCE	POLES	MAIL CRANES	ICING DOCKS	ORE AND COAL DOCKS	CATTLE CHUTES
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
ALABAMA	NOTE 1																																					
ALASKA	NOTE																																					
ARIZONA	G O R-5	1960	14-0	14-0	15-0	20-0	20-0	14-0	11-6	13-0	22-0	22-0	23-0	22-0	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-6[3]	8-6	0-8	4-8			4-0	7-3[10]	8-6	3-0	6-0	0-4	3-0	8-6	E	7-8	8-6	8-6
ARKANSAS	CASE R 1012	1956	14-0	14-0	14-0	17-0	20-0	14-0	13-0	13-0	22-0	22-0	22-0	23-0	17-0[3]	18-0[4]	8-6	8-0	8-6	8-0	7-0[3,5]	7-0[6]	0-8	5-0	4-0	5-9[7]	4-0	8-0	8-6	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6
CALIFORNIA	G O 26-D	1964	14-0	14-0	15-0	20-0	20-0	14-0	13-0	13-0	22-6	22-6	22-6	22-6	18-0	18-0[4]	8-6	8-0	8-6	8-0	8-6	8-6	0-8	4-8			4-0	7-6	8-6	3-0	6-0	0-4	3-0	8-6	6-5[11]	7-8	8-6	8-6
CANADA	G O E-2	1965	13-0	13-6	14-0	15-0	18-0	13-6	12-0	12-0	22-6	22-6	22-6	22-6	22-6	22-6	8-4¼	8-0	8-4¼	8-0	8-4¼	8-4¼	[19]	[19]	[19]	[19]	4-0		8-4¼		8-4¼			8-4¼	7-1¾[11]	8-4¼	8-4¼	8-4¼
COLORADO	DEC 55621	1961	14-0	14-0	15-0	17-0	20-0	14-0	13-0	13-0	22-6	22-0	22-6	23-0	17-0[3]	18-0[4]	8-6	8-0	8-6	8-0	7-0	8-0[6]	0-8	5-0	4-0	5-9[7]	4-0	8-6	8-6	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6
CONNECTICUT	DOCK 8995	1956	13-0	13-0	5-0	18-0	19-0	14-0	13-0	13-0	18-0[13]	18-0[13]	18-0[13]	18-0[3]	18-0[3]	18-0	8-6	8-0	8-6	8-0	8-0[3]	8-0	0-8	5-2			4-0	8-6[8,10]	8-6	3-0	6-0	0-4	3-0	8-6	6-5[11]	8-6	8-0	8-6
DELAWARE	ORDER 214	1955	14-0	13-6	15-0	18-0	19-0	13-6	13-0	13-0	22-0	22-0	22-0	22-0	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-0[3]	8-0	0-8	5-1	4-0	5-7[9]	4-0	8-6[8,10]	8-6	3-0	6-0	0-4	3-0	8-6	6-5[11]	7-8	E	8-6
DIST OF COLUMBIA	ORDER	1954	14-0	14-0	15-0	18-0	19-0	14-0	13-0	13-0	22-0	22-0	22-0	22-0	18-0[3]	18-0	8-6	8-0	8-6	8-0	8-0	8-0	0-8	4-8	4-0	5-7[7]			8-6	3-0	6-0	0-4	3-0	8-6	8-6	8-6	8-6	8-6
FLORIDA	ORDER 1871	1953	13-6	13-6	13-6	19-0	19-0	13-6	13-0	13-0	22-0	22-0[2]	22-0	22-0[2]	17-0	17-0	8-0	8-0	8-0	8-0[2]	8-0	8-0	0-8	4-8	CFH	5-9			8-0	3-0	6-0	0-4	3-0	10-0	6-5[11]	7-8	8-0	8-0
GEORGIA	NOTE 1																																					
IDAHO	G O 99	1955	14-0	14-0	15-0	20-0	20-0	14-0	13-0	13-0	22-6	22-6	22-6	22-6	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-6[3]	8-6[3]	0-8	4-8	4-0	7-3	4-0	8-6[11]	8-0	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6
ILLINOIS	G O 22	1920	13-6[5]	13-6[5]	15-0	17-0[15]	19-0[7]		13-6	13-6	21-6	21-3	21-6	21-6[2]	H		8-0	8-0	8-0	8-0[2]	7-0[3]	7-0	0-4	4-6	0-8	5-1[9]	CFH	5-8	8-6	2-8				9-0	8-0	8-0	8-0	8-0
INDIANA	STATUTES	1951									22-0	22-0[2]	22-0	22-0	22-0	22-0	8-0	8-0[2]	8-0	8-0[2]	8-0	8-0							8-0					8-0	8-0	8-0	8-0	8-0
IOWA	DOCK R-1281	1936	14-0[15]	13-6[15]	15-0	17-0[15]	19-0[7]		13-6	13-6	22-0	22-0	22-0	22-0[2]	H		8-0	8-0	8-0	8-0[2]	7-0[3]	7-0	0-4	4-6	0-8	5-1[9]	CFH	5-8	8-0	2-8				8-0	6-3[11]	8-0	7-0	8-0
KANSAS	DOCK 58144-R	1958	14-0	14-0	14-0	17-0	20-0	14-0	13-0	13-0	22-6	22-0	22-6	23-0	17-0[3]	18-0[4]	8-6	8-0	8-6	8-0	7-0[5]	7-0[6]	0-8	5-0	4-0	5-9[7]	4-0	8-0	8-6	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6
KENTUCKY	STATUTES	1942											22-0																									
LOUISIANA	NOTE																																					
MAINE	G O 2	1956									22-0	22-0	22-0	22-0[2]	17-0[3]	17-0	8-0	8-0	8-0	8-0[2]	7-0[3]	8-0	0-12	5-4	4-0	5-9[7]		[10]	8-0	3-2	5-5	0-4	3-0	8-0	6-1[11]	6-0	6-0	8-0
MARYLAND	ORDER 50138	1953	14-0	13-6	15-0	18-0	19-0	13-6	13-0	13-0	22-0	22-0	22-0	22-0	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-0[3]	8-0	0-8	5-1	4-0	5-7[9]	4-0	8-6[8,10]	8-6	3-0	6-0	0-4	3-0	8-6	6-5[11]	7-8	E	8-6
MASSACHUSETTS	STATUTES	1956	13-0	13-0	13-0	17-0	17-0	17-0	13-0	13-0	22-6	22-6[2]	22-6	22-6[2]	22-6	22-6	8-6	8-6[2]	8-6	8-6[2]	8-6					5-9[7]			8-6	3-0	6-6			8-6	8-6	8-6	8-6	8-6
MICHIGAN	STATUTES	1957	14-0	14-0	14-0	14-0	14-0	14-0	14-0	14-0	22-6	E	E	22-6	22-6	22-6	8-6	E	E	8-6	8-6	8-6							E	E	E	E	E	8-6	E	E	E	E
MINNESOTA	STATUTES	1943	14-0	14-0	14-0	17-0	19-0	14-0	14-0	14-0	22-0	22-0	22-0	22-0	22-0[3]	22-0	8-6	8-6	8-6	8-6	8-6[3]	8-6							8-6					8-6	8-6	8-6	8-6	8-6
MISSISSIPPI	NOTE 1																																					
MISSOURI	G O 24	1959	14-0	14-0	14-0	17-0	19-0	14-0	14-0	13-6	22-0	22-0	22-0	22-0	22-0	22-0	8-6	8-0	8-6	8-6	8-6[3]	8-6	0-4	4-6	0-8	5-1[9]	CFH	5-9	8-6	4-0	5-0[10] 8-0	0-3	4-2	8-6	6-5[11]	8-6	8-6	8-6
MONTANA	ORDER 2597	1956	14-0	14-0	15-0	20-0	20-0	14-0	13-0	13-0	22-6	22-6	22-6	22-6	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-6[3]	8-6	0-8	4-8	4-0	5-9[7]	4-0	8-6[10]	8-0	3-0	6-0	0-4	3-0	8-6	8-6	5-9	8-6	8-6
NEBRASKA	ORDER 24501	1963	14-0	14-0	15-0	17-0	20-0	14-0	13-0	13-0	22-6	22-0	23-0	23-0	17-0[3]	18-0[4]	8-6	8-0	8-6	8-0	7-0[3]	7-0[6]	0-8	5-0	4-0	5-9[6]	4-0	8-6	8-6	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6
NEVADA	CASE 1159	1947	14-0	14-0	15-0	20-0	20-0	20-0	11-6	13-0	22-0	22-0	23-0	22-0	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-6[3]	8-6	0-8	4-8			4-0	7-3[10]	8-6	3-0	6-0	0-4	3-0	8-6	E	7-8	8-6	8-6
NEW HAMPSHIRE	ORDER 6922	1956	14-0	14-0	15-0	18-0	18-0	14-0[16]	13-0	13-0	21-0	21-0	21-0	21-0	17-0[3]	17-0	8-0[14]	8-0[14]	8-0[14]	8-0[14]	7-0[3]	8-0	0-12	5-4	4-0	5-9[7]		[10]	8-6	3-2	5-5	0-4	3-0	8-6	6-1[11]	6-0	6-0	8-6
NEW JERSEY	NOTE 1																																					
NEW MEXICO	ORDER 2202	1957	14-0	14-0	15-0	17-0	20-0	14-0	13-0		22-6	22-0	22-6	23-0	17-0[3]	18-0[4]	8-6	8-0	8-6	8-0	7-0[5]	7-0[6]	0-8	4-8	4-0	5-9[7]	4-0	8-0	8-6	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6
NEW YORK	STATUTES	1961	13-6	13-6	15-0	18-0	19-0	13-6	13-6	13-6	22-0	22-0	22-0	22-0	18-0[3]	18-0	8-6	8-0	8-6	8-0	8-0[3]	8-0	0-8	5-1	4-0	5-7[9]	4-0	8-6[8,10]	8-6	3-0	6-0	0-4	3-0	8-6	6-5[11]	8-0	E	8-0
NORTH CAROLINA	NOTE 1																																					
NORTH DAKOTA	STATUTES	1943	13-0	13-0	13-0	13-0	13-0	13-0	13-0	13-0	21-0[2]	21-0[2]	21-0	21-0[2]	21-0	21-0	8-0[3]	8-0[2]	8-0	8-0[2]	8-0	8-0					4-0	8-0	8-0					8-0	8-0	8-0	8-0	8-0
OHIO	ORDER 26531	1958	14-0	14-0	15-0	15-0	18-0	14-0			21-0	21-0[2]	21-0	21-0[2]	21-0	21-0	8-0	8-0[2]	8-0	8-0[2]	8-0	8-0							8-0					8-0	8-0	8-0	8-0	8-0
OKLAHOMA	ORDER 33347	1956	14-0	14-0	14-0	17-0	20-0	14-0	13-0	13-0	22-0	22-0	22-0	23-0	17-0[3]	18-0[4]	8-6	8-0	8-6	8-0	7-0[3,5]	7-0[6]	0-8	5-0	4-0	5-9	4-0	8-0	8-6	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6
OREGON	ORDER 33700	1955	15-0	14-0	15-0	20-0	20-0	14-0	13-0	13-0	22-6	22-6	22-6	22-6	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-6	8-6	0-8	4-8			4-0	7-3[10]	8-6	3-0	6-0	0-4	3-0	8-6	8-6	7-8	8-6	8-6
PENNSYLVANIA	ORDER	1954	13-6	13-6	15-0	18-0	19-0	13-6	13-6		22-0	22-0	22-0	22-0	18-0[3]	18-0	8-6	8-0	8-6	8-0	8-0[3]	8-0	0-8	5-1	4-0	5-7[9]	4-0	8-6[8,10]	8-6	3-0	6-0	0-4	3-0	8-6	6-5[11]	8-0	E	8-6
RHODE ISLAND	DOCK 608	1955	13-0	14-0	15-0	18-0	19-0	14-0	13-0	14-0	18-0	18-0	18-0	18-0	18-0[3]	18-0	8-6	8-0	8-6	8-0	8-0[3]	8-0	0-8	5-2			4-0	8-6[8,10]	8-6	3-0	6-0	0-4	3-0	8-6	6-5[11]	8-6	8-0	8-6
SOUTH CAROLINA	NOTE 1																																					
SOUTH DAKOTA	ORDER F-2465	1957									22-6	22-6	22-6[2]	22-6	17-0	22-6	8-6	8-0	8-0[2]	8-6	7-0	8-6	0-8	4-8	CFH	5-9			8-0			0-4	3-0	8-6	8-6	8-6	8-6	8-6
TENNESSEE	STATUTES	1949	14-0	13-0	14-0	18-0	18-0	14-0	13-0	13-0	22-0	22-0	22-0	22-0	17-0	17-0[4]	8-0	8-0	8-0	8-0	8-0	8-0	0-8	4-8	4-0	5-9	4-0	7-6	8-0		6-6	0-4	3-0	8-0	6-5[11]	7-0	8-0	8-0
TEXAS	STATUTES	1948									22-0	22-0	22-0	22-0[2]	22-0[3]	22-0	8-6	7-6	8-6	8-6[2]	8-6[3]	8-6	0-12	4-6					8-6	2-6	5-6	0-6	4-0	8-6	E	7-0	8-6	8-6
UTAH	G O 66	1953	14-0	14-0	15-0	17-0	20-0	14-0	11-6	11-6	22-6	22-6	22-6	22-6	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-6[3]	8-6	0-8	4-8	1-9	5-8[9]	4-0	7-3[10]	8-6	3-0	6-0	0-4	3-0	8-6	E	7-8	8-6	8-6
VERMONT	STATUTES	1951										22-0	22-0				8-0	8-0	8-0	8-0	8-0	8-0																
VIRGINIA	NOTE 1																																					
WASHINGTON	G O T-8499	1957	14-0	14-0	15-0	20-0	20-0	14-0	13-0	13-0	22-6	22-6	22-6	22-6	18-0[3]	18-0[4]	8-6	8-0	8-6	8-0	8-6[3]	8-6	0-8	4-8	4-0	5-9	4-0	8-6[10]	8-0	3-0	6-0	0-4	3-0	8-6	8-6	5-9	8-6	8-6
WEST VIRGINIA	G O 121	1953		13-0	15-0	15-0	18-0	13-0	13-0	13-0																												
WISCONSIN	STATUTES	1951	14-0	14-0	14-0	14-0	14-0	14-0	14-0	14-0	22-0	22-0[2]	22-0	22-0[2]	22-0	22-0	8-6	E	8-6	8-6[2]	8-6	8-6	0-4 0-8	4-6 5-1	1-9	6-0[9]	5-0	6-4	8-6	E	E	E	E	12-0	E	8-6	8-6	8-6
WYOMING	DOCK 9287	1959	14-0	14-0	15-0	17-0	20-0	14-0	13-0	13-0	22-6	22-0	23-6	23-0	17-0[3]	18-0[4]	8-6	8-0	8-6	8-0	7-0[3,5]	7-0[6]	0-8	5-0	4-0	5-9[7]	4-0	8-6	8-6	3-0	6-0	0-4	3-0	8-6	8-6	6-8[12]	8-6	8-6

NOTES

THIS CHART FOR INFORMATION ONLY - NO LIABILITY CAN BE ASSUMED

ARCHITECTS, CONTRACTORS ETC. SHOULD CHECK WITH RAILROAD INVOLVED

DIMENSIONS SHOWN IN FEET AND INCHES
- ARE FOR TANGENT TRACK - MOST LAWS SPECIFY INCREASES FOR CURVED AND SUPERELEVATED TRACK
- VERTICAL - MEASURED FROM TOP OF RAIL, EXCEPT CANADA - BASE OF RAIL FOR OTHER THAN PLATFORMS
- HORIZONTAL MEASURED FROM CENTER LINE OF TRACK
- APPLY TO NEW CONSTRUCTION, SOME RECONSTRUCTION AND SOME EXTENSIONS
- SOME CAN BE VARIED UPON APPROVAL OF APPLICATION BY GOVERNING BODY
- ARE BASED ON MAXIMUM CAR SIZE FOR ARIZONA, CALIFORNIA, IDAHO, MINNESOTA, MONTANA, NEVADA, NORTH DAKOTA, OREGON AND WASHINGTON
- ALL ARE MINIMUM EXCEPT COLUMNS 24, 26, 28, 31 AND 33 WHICH ARE MAXIMUM

HAWAII OMITTED - NO COMMON CARRIER RAILROADS

C - CONDITIONAL SEE SPECIFIC REGULATION
CFH - CAR FLOOR HEIGHT
E EXEMPT
H - HEIGHT OF CARS GOVERNS

COLUMN 2 SHOWS BASIC REGULATION
- 3 SHOWS BASIC DATE OR DATE OF LATEST AMENDMENT
- 7 & 8 APPLY TO HAND AND MECHANICALLY OPERATED SWITCHES EXCEPT AS NOTED
- 12 & 18 PREVAILS FOR ALL ITEMS NOT OTHERWISE PROVIDED FOR
- 13 & 19 BRIDGES SUPPORTING TRACKS
- 14 & 20 BRIDGES SPANNING TRACKS
- 24 & 25 PASSENGER PLATFORMS
- 26 & 27 FREIGHT PLATFORMS ON SIDE TRACKS EXCEPT AS NOTED
- 28 & 29 FREIGHT PLATFORMS ON SIDE TRACKS
  - STEPPED PLATFORMS ARE NOT GENERALLY ALLOWED
- 35 OTHER THAN TROLLEY CONTACT POLES
- 36 TO CENTER OF STAND EXCEPT AS NOTED
- 37 APPLIES TO BOTH SUPPORTS AND PLATFORMS EXCEPT AS NOTED

1. NO CURRENT REGULATION - CHECK WITH RAILROAD INVOLVED
2. LESSER CLEARANCES NOT PERMITTED IN QUADRANTS
3. ENGINE HOUSES AND SHOP BUILDINGS EXEMPT OR PERMITTED LESSER DIMENSIONS
4. ONLY IF TRACKS END WITHIN BUILDINGS
5. MAY BE REDUCED TO 5-9 IF 8-3 (8-6 FOR WYOMING) PROVIDED ON OPPOSITE SIDE
6. MAY BE REDUCED TO 5-9 IF 8-0 (8-6 FOR NEB & WYO) PROVIDED ON OPPOSITE SIDE
7. ONLY IF 8-0 (7-3 FOR MONT & WYO, 8-6 D.C., MASS., S DAK) PROVIDED ON OPPOSITE SIDE
8. MAY BE LESS ON ONE SIDE IF FULL GENERAL (COL 18) PROVIDED ON OPPOSITE SIDE
9. PASSENGER PLATFORMS ONLY
10. MAY BE 8-0 AT 4-6 FOR REFRIGERATOR CAR PLATFORMS ONLY
11. TO ENDS OF ARMS IN OPERATING POSITION
12. FOR PLATFORMS AT CAR EAVE HEIGHT - SUPPORTS TO BE 8-0 (8-6 FOR TEXAS)
13. FOR MAIN TRACKS ALL OTHERS 22-0
14. 8-6 FOR MAIN AND PASSING TRACKS
15. FOR FREIGHT TRACKS CAN BE 13-0 FOR PASSENGER TRACKS
16. FOR HAND OPERATED SWITCHES - MAY BE 15-0 FOR MECHANICALLY OPERATED SWITCHES
17. FOR HAND OPERATED SWITCHES - MAY BE 17-0 FOR MECHANICALLY OPERATED SWITCHES
18. PARALLEL LEAD TRACKS 18-0
19. REGARDING CANADA - CHECK STANDARD CLEARANCE DIAGRAM, APPROVED BY BOARD OF TRANSPORT COMMISSIONERS FOR CANADA, FOR RAILWAY INVOLVED

1-15-67
6-1-65
7-20-61
10-1-60

Report on Assignment 2

Compilation of the Railroad Clearance Requirements of the Various States

R. D. Erhardt (chairman, subcommittee), J. D. Batchelder, E. S. Birkenwald, J. A. Crawford, M. E. Dust, E. F. Grecco, O. H. Jensen, R. J. Jones, J. L. Kampwirth, A. J. Kozak, M. D. Murphy, F. B. Persels, C. E. Peterson, A. G. Richmond, E. C. Smith, J. L. Trotman, W. S. Tustin, M. E. Vosseller, J. W. Wallenius.

Your committee submits as information the accompanying chart showing the clearance requirements of the various states, brought up-to-date as of January 15, 1967. This revised chart supersedes the chart last previously published in Bulletin 561, December 1960, following page 412.

Your committee would appreciate receiving information from the membership of the Association regarding any changes in the legal clearance requirements of the various states.

Report on Assignment 3

New Methods and Electronic Devices for Recording Measurements of Clearances of Structures Along Right-of-Way and Overall Dimensions of Cars and Loads in Yards and at Interchange Points, Looking to the Possible Use of a Computer Program for Routing High and Wide Loads

F. B. Persels (chairman, subcommittee), G. J. Adams, J. D. Batchelder, J. A. Crawford, R. T. Dedow, M. E. Dust, R. D. Erhardt, G. P. Fosque, J. G. Greenlee, W. T. Hammond, G. E. Henry, C. F. Intlekofer, E. C. Lawson, C. E. Peterson, C. H. Stephenson, J. L. Trotman, W. S. Tustin, M. E. Vosseller, J. W. Wallenius.

Your committee sent a questionnaire to the chief engineering officers of Class I railroads requesting information as to whether or not their railroad was using or considering the use of (1) any new methods or electronic devices for recording measurements of dimensions of cars and loads in yards and at interchange points and (2) a computer program for routing high and wide loads.

A total of 74 replies were received and a summation of these replies is as follows:

The answers to question (1) revealed that 11 roads are using electronic devices and 6 roads are considering use of electronic devices. The answers to question (2) revealed that two roads are using a computer program, six roads are now working up a computer program and 20 roads are considering use of a computer program. A negative answer to both questions was made by 38 roads.

Your committee has requested an appropriation in the 1968 Engineering Division Budget for investigation of electronic equipment for determining clearance dimensions of loads.

This progress report is submitted as information.

Report on Assignment 6

Feasibility of Formulating a More Complete Method, for Use of Transportaton Departments, in Reporting Loads of Excessive Dimensions to Minimize Necessity for Requesting Additional Information

Collaborating as Necessary or Desirable with the Mechanical Division, AAR

J. E. Beran (chairman, subcommittee), G. J. Adams, D. H. Brown, J. A. Crawford, R. T. Dedow, M. E. Dust, W. T. Hammond, G. E. Henry, G. P. Huhlein, J. L. Kampwirth, A. J. Kozak, B. W. McCurdy, J. R. Moore, M. D. Murphy, C. H. Stephenson, J. L. Trotman, W. S. Tustin, M. Van Kuiken, M. E. Vosseller.

Your committee revised the proposed instructions and procedures which it had developed so as to incorporate those changes suggested by the Mechanical Division's Committee on Loading Rules, and the revised instructions and procedures were resubmitted to them through the executive secretary's office. Subsequent to this, the Committee on Car Service, Operating-Transportation Division, AAR, became interested in this problem.

It was decided to have a meeting of representatives of all three committees to discuss this matter. As a result of this meeting, further revisions, primarily semantical, were deemed necessary in the proposed instructions and procedures.

Your committee is making these revisions and is hopeful of receiving the final approval and concurrence of both the Mechanical Division and the Operating-Transportation Division in the ensuing year.

This status report is submitted as information.

Report of Committee 24—Cooperative Relations with Universities

°R. H. Beeder, *Chairman*
V. J. Roggeveen,
Vice Chairman
°A. V. Johnston
R. H. Lee
W. A. Oliver

°H. E. Hurst
°W. T. Hammond
°J. F. Davison
T. M. Adams
B. C. Anderson
W. S. Autrey
J. B. Babcock (E)
G. Baylor
J. H. Brown
N. D. Bryant
W. R. Catching
J. B. Clark
A. W. Cooper
T. P. Cunningham
B. M. Davidson
R. P. Davis (E)
D. G. Elack
J. T. Evans
R. J. Fisher
L. C. Gilbert
C. E. R. Haight
W. W. Hay
C. L. Heimbach
C. J. Henry
L. J. Hoffman

E. Y. Huang
W. H. Huffman
F. O. Johnson
C. Johnston
T. D. Kern
W. S. Kerr
H. E. Kirby (E)
J. W. Laurent
B. B. Lewis
M. L. Manheim
R. G. Michael
J. F. Pearce
R. D. Pedersen
J. A. Peebles
G. B. Pruden
R. B. Rice
J. A. Rust
T. D. Schultz
P. S. Settle
G. Reed Shaw
R. M. Soberman
W. D. Taylor
D. O. Van Strien
H. M. Williamson
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman and vice chairman, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 24.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Stimulate greater appreciation on the part of railway managements of
   (a) the importance of bringing into the service selected graduates of colleges and universities, and
   (b) the necessity of providing adequate means for recruiting such graduates and of retaining them in the service.

   Progress report, presented as information .... page 278

2. Stimulate among college and university students a greater interest in the science of transportation and its importance in the national economic structure by
   (a) cooperating with and contributing to the activities of student organizations in colleges and universities, and
   (b) presenting to students and their counselors a positive approach to the attractive and interesting features of the railroad industry and the advantages of choosing railroading as a career.

   Progress report, presented as information .... page 284

3. The cooperative system of education, including summer employment in railway service.

   Progress report, presented as information .... page 286

5. Ways in which railroads can cooperate with universities in developing research, including the revising of "Suggested Topics for Theses on Railroad Subjects."
   Progress report, presented as information .... page 287
6. Procedures for orienting and developing newly employed engineering personnel.
   No report.
7. Stimulate an interest by college and university staff members in current railroad problems and practices, including AREA membership.
   No report.
8. Current changes in engineering education and their implications regarding employment of future graduates by the railroad industry.
   No report.

THE COMMITTEE ON COOPERATIVE RELATIONS WITH UNIVERSITIES,
R. H. BEEDER, *Chairman.*

AREA Bulletin 610, December 1967.

Report on Assignment 1

Stimulate Greater Appreciation on the Part of Railway Managements of

(a) The Importance of Bringing into the Service Selected Graduates of Colleges and Universities, and

(b) The Necessity for Providing Adequate Means for Recruiting Such Graduates and of Retaining Them in Service

A. V. JOHNSTON (chairman, subcommittee), B. G. ANDERSON, R. H. BEEDER, N. D. BRYANT, W. R. CATCHING, B. M. DAVIDSON, J. F. DAVISON, J. W. LAURENT, G. B. PRUDEN, V. J. ROGGEVEEN, J. A. RUST, W. D. TAYLOR, H. M. WILLIAMSON.

During the current year your committee undertook an investigation into the career background of railroad officers at management levels. The purpose of this study was to catalogue biographical and salary data for this group in order to illustrate the career opportunities to be found in the railroad industry both within and outside the engineering departments.

To produce reliable results, a broad investigation has been made of all United States railroad officers with annual salaries of $30,000 or more that were in active service at the end of the year 1966. This group was selected because every officer at this salary level could be readily identified in the comprehensive annual reports which must be filed with the Interstate Commerce Commission by each Class I line-haul and switching and terminal company. Biographical sketches from standard reference works supplied the personal information and career highlights for a large percentage of these officers. Thus all of the backup data used in the preparation of the four tables that summarize this study was obtained from sources that are open to public inspection.

(Text continued on page 283)

COMPENSATION, AGE AND CAREER BACKGROUND OF U.S. RAILROAD OFFICERS PAID $30,000 OR MORE IN 1966

TABLE 1. CHIEF EXECUTIVE OFFICERS AND DEPARTMENT HEADS
OF 19 MAJOR RAILROADS WITH TOTAL OPERATING REVENUES MORE THAN $200,000,000

Source: Railroad Annual Reports Form A to the Interstate Commerce Commission (year 1966)
Who's Who in America, World Who's Who in Commerce and Industry (A.N. Maquis Co.)
Who's Who in Railroading (Simmons-Boardman)

	COMPENSATION IN 1966	AGE IN 1966	AGE WHEN APPOINTED	LEVEL OF EDUCATION	DEPARTMENT WHERE CAREER STARTED
TOP EXECUTIVE OFFICER (19 Officers)	Highest $179,650 Average 131,192 Lowest 86,233	Oldest 71 Average 60.0 Youngest 48	Oldest 59 Average 49.9 Youngest 41	Eng. Degree 8 Law Degree 4 Other Degree 2 Some College 3 No College 2	Executive 1 Engineering 9 Transportation 1 Legal 4 Finance&Acctg. 3 Traffic 1
TOP OPERATING OFFICER (19 Officers)	Highest $ 85,000 Average 59,120 Lowest 40,000	Oldest 65 Average 55.7 Youngest 44	Oldest 62 Average 52.7 Youngest 42	Eng. Degree 7 Other Degree 1 Some College 3 No College 5 Unknown* 3	Engineering 7 Mechanical 1 Transportation 10 Unknown* 1
TOP LEGAL OFFICER (19 Officers)	Highest $ 92,220 Average 59,888 Lowest 32,500	Oldest 69 Average 57.2 Youngest 44	Oldest 65 Average 49.6 Youngest 39	Law Degree 17 Unknown* 2	Legal 17 Unknown* 2
TOP FINANCE AND ACCOUNTING OFFICER (17 Officers)	Highest $ 84,825 Average 51,760 Lowest 30,060	Oldest 67 Average 55.7 Youngest 40	Oldest 64 Average 50.4 Youngest 39	Eng. Degree 1 Law Degree 1 Other Degree 8 Some College 3 No College 2 Unknown* 2	Engineering 1 Legal 1 Finance&Acctg. 13 Unknown* 2
TOP TRAFFIC OFFICER (19 Officers)	Highest $ 71,200 Average 51,151 Lowest 33,000	Oldest 65 Average 58.6 Youngest 47	Oldest 65 Average 55.2 Youngest 42	Eng. Degree 1 Other Degree 2 Some College 6 No College 8 Unknown* 2	Mechanical 1 Transportation 2 Traffic 15 Unknown* 1
TOP OFFICERS ALL OTHER DEPARTMENTS (38 Officers) note (a)	Highest $ 68,100 Average 42,734 Lowest 30,000	Oldest 69 Average 57.3 Youngest 42	Oldest 64 Average 50.9 Youngest 40	Eng. Degree 5 Law Degree 6 Other Degree 8 Some College 7 No College 3 Unknown* 9	Engineering 4 Mechanical 4 Transportation 3 Legal 4 Finance&Acctg. 2 Other Depts. 14 Unknown* 7
TOTAL TOP OFFICERS ALL DEPARTMENTS (131 Officers)	Highest $179,650 Average 62,820 Lowest 30,000	Oldest 71 Average 57.5 Youngest 40	Oldest 65 Average 51.4 Youngest 39	Eng. Degree 22 Law Degree 28 Other Degree 21 Some College 22 No College 20 Unknown* 18	Executive 1 Engineering 21 Mechanical 6 Transportation 16 Legal 26 Finance&Acctg. 18 Traffic 16 Other Depts. 14 Unknown* 13

* Biographical information incomplete or not available

(a) Other department officers include 13-labor relations and personnel, 9-purchases and stores, 8-real estate or other resource development, 5-public relations, 3-other functions.

COMPENSATION, AGE AND CAREER BACKGROUND OF U.S. RAILROAD OFFICERS PAID $30,000 OR MORE IN 1966

TABLE 2. OFFICERS, OTHER THAN CHIEF EXECUTIVES AND DEPARTMENT HEADS, OF 19 MAJOR RAILROADS WITH TOTAL OPERATING REVENUES MORE THAN $200,000,000

Source: Railroad Annual Reports Form A to the Interstate Commerce Commission (year 1966)
Who's Who in America, World Who's Who in Commerce and Industry (A.N. Maquis Co.)
Who's Who in Railroading (Simmons-Boardman)

	COMPENSATION IN 1966	AGE IN 1966	AGE WHEN APPOINTED	LEVEL OF EDUCATION	DEPARTMENT WHERE CAREER STARTED
EXECUTIVE DEPARTMENT (40 Officers)	Highest $150,000 Average 63,144 Lowest 30,000	Oldest 77 Average 56.3 Youngest 39	Oldest 67 Average 50.4 Youngest 36	Eng. Degree 10 Law Degree 7 Other Degree 11 Some College 5 No College 4 Unknown* 3	Executive 4 Engineering 10 Mechanical 1 Transportation 7 Legal 7 Finance&Acctg. 5 Traffic 1 Other Depts. 3 Unknown* 2
OPERATING DEPARTMENT (79 Officers) note (b)	Highest $ 56,749 Average 36,311 Lowest 30,000	Oldest 65 Average 53.1 Youngest 38	Oldest 63 Average 48.2 Youngest 34	Eng. Degree 39 Other Degree 3 Some College 7 No College 16 Unknown* 14	Engineering 35 Mechanical 12 Transportation 22 Other Dept. 1 Unknown* 9
LEGAL DEPARTMENT (50 Officers)	Highest $ 65,050 Average 38,370 Lowest 30,000	Oldest 69 Average 54.3 Youngest 39	Oldest 62 Average 48.2 Youngest 38	Law Degree 45 Unknown* 5	Legal 45 Other Dept. 1 Unknown* 4
FINANCE AND ACCOUNTING DEPARTMENT (34 Officers)	Highest $ 58,000 Average 37,635 Lowest 30,000	Oldest 63 Average 51.9 Youngest 35	Oldest 56 Average 45.8 Youngest 35	Law Degree 6 Other Degree 14 Some College 4 No College 1 Unknown* 9	Legal 4 Finance&Acctg. 22 Unknown* 8
TRAFFIC DEPARTMENT (53 Officers)	Highest $ 55,400 Average 35,904 Lowest 30,000	Oldest 64 Average 54.3 Youngest 35	Oldest 63 Average 50.9 Youngest 35	Eng. Degree 1 Law Degree 4 Other Degree 11 Some College 14 No College 10 Unknown* 13	Engineering 1 Transportation 2 Legal 4 Finance&Acctg. 2 Traffic 30 Other Depts. 2 Unknown* 12
ALL OTHER DEPARTMENTS (15 Officers) note (c)	Highest $ 45,000 Average 32,638 Lowest 30,000	Oldest 63 Average 56.0 Youngest 49	Oldest 58 Average 50.3 Youngest 37	Eng. Degree 1 Law Degree 1 Other Degree 2 Some College 2 No College 3 Unknown* 6	Engineering 1 Mechanical 1 Transportation 1 Finance&Acctg. 1 Other Depts. 5 Unknown* 6
TOTAL ALL DEPARTMENTS (271 Officers)	Highest $150,000 Average 40,535 Lowest 30,000	Oldest 77 Average 54.1 Youngest 35	Oldest 67 Average 48.9 Youngest 34	Eng. Degree 51 Law Degree 63 Other Degree 41 Some College 32 No College 34 Unknown* 50	Executive 4 Engineering 47 Mechanical 14 Transportation 32 Legal 60 Finance&Acctg. 30 Traffic 31 Other Depts. 12 Unknown* 35

* Biographical information incomplete or not available

(b) Operating department officers include 48-general operating, 17-engineering, 8-mechanical, 6-transportation.

(c) Other department officers include 8-labor relations and personnel, 2-real estate or other resource development, 2-public relations, 3-other functions.

COMPENSATION, AGE AND CAREER BACKGROUND OF U.S. RAILROAD OFFICERS PAID $30,000 OR MORE IN 1966

TABLE 3. CHIEF EXECUTIVES AND SUBORDINATE OFFICERS
OF 36 SMALLER RAILROADS WITH TOTAL OPERATING REVENUES LESS THAN $200,000,000

Source: Railroad Annual Reports Form A to the Interstate Commerce Commission (year 1966)
Who's Who in America, World Who's Who in Commerce and Industry (A.N. Marquis Co.)
Who's Who in Railroading (Simmons-Boardman)

	COMPENSATION IN 1966	AGE IN 1966	AGE WHEN APPOINTED	LEVEL OF EDUCATION	DEPARTMENT WHERE CAREER STARTED
EXECUTIVE DEPARTMENT (41 Officers)	Highest $ 91,840 Average 55,772 Lowest 31,400	Oldest 83 Average 58.3 Youngest 34	Oldest 61 Average 49.3 Youngest 34	Eng. Degree 13 Law Degree 6 Other Degree 8 Some College 6 No College 4 Unknown* 4	Executive 1 Engineering 14 Transportation 8 Legal 5 Finance&Acctg. 4 Traffic 4 Unknown* 5
OPERATING DEPARTMENT (25 Officers) note (d)	Highest $ 51,240 Average 36,921 Lowest 30,289	Oldest 66 Average 55.9 Youngest 47	Oldest 62 Average 50.6 Youngest 39	Eng. Degree 8 Other Degree 2 Some College 3 No College 8 Unknown* 4	Engineering 9 Mechanical 3 Transportation 8 Unknown* 5
LEGAL DEPARTMENT (11 Officers)	Highest $ 46,800 Average 36,769 Lowest 30,040	Oldest 64 Average 53.4 Youngest 40	Oldest 56 Average 47.3 Youngest 39	Law Degree 10 Unknown* 1	Legal 10 Unknown* 1
FINANCE AND ACCOUNTING DEPARTMENT (14 Officers)	Highest $ 43,090 Average 33,576 Lowest 30,000	Oldest 68 Average 55.1 Youngest 45	Oldest 63 Average 49.6 Youngest 36	Eng. Degree 1 Law Degree 4 Other Degree 2 Some College 3 No College 2 Unknown* 2	Engineering 1 Mechanical 1 Legal 3 Finance&Acctg. 7 Unknown* 2
TRAFFIC DEPARTMENT (17 Officers)	Highest $ 50,000 Average 35,033 Lowest 30,000	Oldest 64 Average 56.1 Youngest 43	Oldest 64 Average 52.6 Youngest 42	Law Degree 3 Other Degree 5 Some College 3 No College 5 Unknown* 1	Engineering 1 Transportation 2 Legal 1 Traffic 11 Unknown* 2
ALL OTHER DEPARTMENTS (3 Officers) note (e)	Highest $ 38,000 Average 33,841 Lowest 30,560	Oldest 58 Average 53.0 Youngest 49	Oldest 50 Average 45.7 Youngest 43	Eng. Degree 1 Other Degree 1 No College 1	Mechanical 1 Transportation 1 Other Dept. 1
TOTAL ALL DEPARTMENTS (111 Officers)	Highest $ 91,840 Average 43,074 Lowest 30,000	Oldest 83 Average 56.4 Youngest 34	Oldest 64 Average 49.8 Youngest 34	Eng. Degree 23 Law Degree 23 Other Degree 18 Some College 15 No College 20 Unknown* 12	Executive 1 Engineering 25 Mechanical 5 Transportation 19 Legal 19 Finance&Acctg. 11 Traffic 15 Other Dept. 1 Unknown* 15

* Biographical information incomplete or not available

(d) Operating department officers include 19-general operating, 2-engineering, 2-mechanical, 2-transportation.

(e) Other department officers include 2-labor relations and personnel, 1-public relations.

COMPENSATION, AGE AND CAREER BACKGROUND OF U.S. RAILROAD OFFICERS PAID $30,000 OR MORE IN 1966

TABLE 4. SUMMARY - ALL OFFICERS PAID $30,000 OR MORE IN 1966
REPORTED BY 55 CLASS I LINE-HAUL AND SWITCHING AND TERMINAL COMPANIES

Source: Railroad Annual Reports Form A to the Interstate Commerce Commission (year 1966)
Who's Who in America, World Who's Who in Commerce and Industry (A.N. Maquis Co.)
Who's Who in Railroading (Simmons-Boardman)

	COMPENSATION IN 1966	AGE IN 1966	AGE WHEN APPOINTED	LEVEL OF EDUCATION	DEPARTMENT WHERE CAREER STARTED
EXECUTIVE DEPARTMENT (100 Officers)	Highest $179,650 Average 73,050 Lowest 30,000	Oldest 83 Average 57.8 Youngest 34	Oldest 67 Average 49.9 Youngest 34	Eng. Degree 31 Law Degree 17 Other Degree 21 Some College 14 No College 10 Unknown* 7	Executive 6 Engineering 33 Mechanical 1 Transportation 16 Legal 16 Finance&Acctg. 12 Traffic 6 Other Depts. 3 Unknown* 7
OPERATING DEPARTMENT (123 Officers) note (f)	Highest $ 65,000 Average 39,959 Lowest 30,000	Oldest 66 Average 54.1 Youngest 38	Oldest 63 Average 49.4 Youngest 34	Eng. Degree 54 Other Degree 6 Some College 13 No College 29 Unknown* 21	Engineering 51 Mechanical 16 Transportation 40 Other Dept. 1 Unknown* 15
LEGAL DEPARTMENT (80 Officers)	Highest $ 92,220 Average 43,260 Lowest 30,000	Oldest 69 Average 54.9 Youngest 39	Oldest 65 Average 48.4 Youngest 38	Law Degree 72 Unknown* 8	Legal 72 Other Dept. 1 Unknown* 7
FINANCE AND ACCOUNTING DEPARTMENT (65 Officers)	Highest $ 84,825 Average 40,055 Lowest 30,000	Oldest 68 Average 53.7 Youngest 35	Oldest 64 Average 48.0 Youngest 35	Eng. Degree 2 Law Degree 11 Other Degree 24 Some College 10 No College 5 Unknown* 13	Engineering 2 Mechanical 1 Legal 8 Finance&Acctg. 42 Unknown* 12
TRAFFIC DEPARTMENT (89 Officers)	Highest $ 71,200 Average 38,993 Lowest 30,000	Oldest 65 Average 55.7 Youngest 35	Oldest 65 Average 52.3 Youngest 35	Eng. Degree 2 Law Degree 7 Other Degree 18 Some College 23 No College 23 Unknown* 16	Engineering 2 Mechanical 1 Transportation 6 Legal 5 Finance&Acctg. 2 Traffic 56 Other Depts. 2 Unknown* 15
ALL OTHER DEPARTMENTS (56 Officers) note (g)	Highest $ 68,100 Average 39,553 Lowest 30,000	Oldest 69 Average 56.0 Youngest 42	Oldest 64 Average 50.3 Youngest 37	Eng. Degree 7 Law Degree 7 Other Degree 11 Some College 9 No College 7 Unknown* 15	Engineering 5 Mechanical 6 Transportation 5 Legal 4 Finance&Acctg. 3 Other Depts. 20 Unknown* 13
GRAND TOTAL ALL DEPARTMENTS (513 Officers)	Highest $179,650 Average 46,775 Lowest 30,000	Oldest 83 Average 55.5 Youngest 34	Oldest 67 Average 49.8 Youngest 34	Eng. Degree 96 Law Degree 114 Other Degree 80 Some College 69 No College 74 Unknown* 80	Executive 6 Engineering 93 Mechanical 25 Transportation 67 Legal 105 Finance&Acctg. 59 Traffic 62 Other Depts. 27 Unknown* 69

* Biographical information incomplete or not available

(f) Operating department officers include 86-general operating, 19-engineering, 10-mechanical, 8-transportation.

(g) Other department officers include 23-labor relations and personnel, 10-real estate or other resource development, 9-purchases and stores, 8-public relations, 6-other functions.

Examination of all Class I annual reports to the ICC disclosed 513 officers employed by 55 different railroads that were paid $30,000 or more in 1966. The number of officers reported by individual companies varied from a high of 50 on one major system to just one officer at this salary level on a number of smaller lines.

Because of the wide variation in the size of reporting companies, and thus in the responsibilities and salaries of principal general officers, separate tabulations have been made for the 19 largest roads and for the 36 smaller companies. The dividing line between major companies and smaller lines in this study was set at $200,000,000 total operating revenues. This point was selected because the larger railroads, as measured by operating revenues, generally reported one or more officers in each of the major departments with salaries of $30,000 or more. The smaller lines, in decreasing revenue order, reported only the chief executive officer and an occasional department head at this salary level. The reader is cautioned that the summary tables include only those officers earning $30,000 or more, so that comparable incumbents with equivalent responsibilities are not included for all railroads. Therefore, the range of salaries and averages may be distorted, particularly, for subordinate officers in each function.

Many interesting comparisons and little known factors can be found in the accompanying four statistical tables. Some of the highlights are:

Table 1. Relatively young age when appointed (average 49.9) of the top executive officers on the 19 largest railroads.

Table 4. Relatively young age when appointed (average 49.8) of all 513 officers paid $30,000 or more.

Table 1. Nearly half (9 of 19) of the top executive officers of the major railroads started in the engineering department, eight with engineering degrees.

Table 4. One-third of the 100 executive department officers on all 55 railroads started in the engineering department, 31 with engineering degrees.

Table 4. Nearly 22% of all officers paid $30,000 or more (with known educational level) have engineering degrees.

Table 4. Nearly 21% of all officers paid $30,000 or more (with known departmental background) started in the engineering department.

Report on Assignment 2

Stimulate Among College and University Students a Greater Interest in the Science of Transportation and Its Importance in the National Economic Structure By

(a) Cooperating with and contributing to the activities of student organizations in colleges and universities, and

(b) Presenting to students and their counselors a positive approach to the attractive and interesting features of the railroad industry and the advantages of choosing railroading as a career

R. H. Lee (chairman, subcommittee), T. M. Adams, R. H. Beeder, J. H. Brown, J. B. Clark, B. M. Davidson, J. T. Evans, C. L. Heimbach, C. J. Henry, L. J. Hoffman, E. Y. Huang, T. D. Kern, W. S. Kerr, J. W. Laurent, B. B. Lewis, H. R. Moore, J. F. Pearce, V. J. Roggeveen, P. S. Settle, Jr., T. G. Schultz, R. M. Soberman.

Subcommittee 2 of Committee 24 reports on the following talks and presentations given by railroad personnel to student organizations during the past year.

H. B. Berkshire, then district engineer, now division superintendent, New York Central, discussed "Civil Engineering and Railroading," in January 1967 at a meeting of the ASCE Student Chapter at Tri-State College (attendance, 50).

H. L. Chamberlain, assistant engineer—structures, Pennsylvania, gave a lecture on "Cooper Loadings and Welded Railroad Bridges" to a structural design class at Tufts College on March 8, 1967 (attendance, 30).

J. W. Diffenderfer, assistant vice president, special services, Pennsylvania, discussed the Northeast Corridor Project at the following institutions:

Bucknell University, February 6, 1967 (attendance, 27)
New York University, April 11, 1967 (attendance, 49)
University of Illinois, April 26, 1967 (attendance, 38)

C. H. Gaut, division engineer, Pennsylvania, talked on "Engineering Opportunities on the Pennsylvania Railroad" and "The Northeast Corridor Project" at a meeting of the ASCE Student Chapter of the University of Delaware, on November 3, 1966 (attendance, 26).

J. E. Lancaster, supervisor of bridges and buildings, Maine Central, talked on "The Civil Engineer in Railroading" and showed the AAR Motion Picture, "Science Rides the High Iron," at a meeting of the ASCE Student Chapter at the University of New Hampshire on February 22, 1967 (attendance, 23).

R. R. Manion, vice president, Operations and Maintenance, Association of American Railroads, talked on "The Engineer in Today's Railroading Business" at the Fifth Annual Engineers' Day of the University of Virginia on October 14, 1966.

A. L. Maynard, engineer bridges and buildings, construction and maintenance, Chesapeake & Ohio—Baltimore & Ohio, discussed structures maintenance and showed two motion pictures on that subject at a meeting of the ASCE Student Chapter at Ohio University on May 2, 1967 (attendance, 15)

L. B. Rasmussen, industrial engineer, Washington Terminal, talked on March 9, 1967, at Cornell University (attendance, 35).

D. H. Shoemaker, chief engineer, Northern Pacific, discussed "The Civil Engineer in the Railroad Industry Today" at a conference of ASCE Student Chapters located in Iowa, Minnesota, North Dakota and South Dakota at the University of North Dakota on April 7, 1967 (attendance, 110).

N. M. Cary, engineer maintenance of way, Southern, talked on "Civil Engineering Applications to Railroading" and showed a film, "Ribbon Rail," at the following institutions:

University of South Carolina, March 7, 1967 (attendance, 35)
Gaston College, March 15, 1967 (attendance, 125)
University of Maryland

B. G. Anderson and C. D. Archibald, assistant chief engineers, Great Northern, talked to two classes at the University of North Dakota on recent projects undertaken by the railroad (attendance, 30)

J. P. Coessens, junior engineer, Bessemer & Lake Erie, discussed civil engineering employment at Villanova University on March 3, 1967 (attendance, 35).

E. B. Dobranetski, Jr., junior engineer, Bessemer & Lake Erie, discussed railroad civil engineering at West Virginia University on March 7, 1967 (attendance, 20).

The following speakers appeared at the University of Illinois during the year:

L. K. Sillcox, honorary vice chairman, New York Airbrake Co., "Coping with Competition," March 7, 1967.

A. L. Sams, vice president and chief engineer, Illinois Central, "New Line Construction on the Illinois Central Railroad," March 22, 1967.

R. D. Timpany, assistant vice president, New York Central, "New Directions in Modern Railroading," April 19, 1967.

R. H. Beeder, chief engineer system, Atchison, Topeka & Santa Fe, "Three Construction Projects on the Santa Fe," May 3, 1967.

Many of the speakers distributed copies of the AREA Engineer Recruiting Brochure entitled "The Railroad Industry—A Challenge and Opportunity for Engineering Graduates," to supplement their talks and give the students and faculty members more knowledge on the employment opportunities on railroads.

On October 2, approximately 80 seniors in the Civil Engineering School at Purdue made an inspection trip to the Association of American Railroads Research Center and the Santa Fe Corwith Yard in Chicago.

The AREA Pictorial Railroad Exhibit was displayed only once during the 1966–67 academic year because it had been withdrawn from service for revision. The Exhibit was displayed during the Engineers' Fair at North Carolina State University on April 21–22, 1967.

During the 1966–67 academic year, there were 56 Student Affiliates at 31 different colleges and universities, as of August 31, 1967, the end of the Student Affiliate year. Since 1960, a total of 190 students have been enrolled in the program from 59 different campuses in the United States and Canada.

Report on Assignment 3

The Cooperative System of Education, Including Summer Employment in Railway Service

W. A. Oliver (chairman, subcommittee), T. M. Adams, J. B. Babcock, R. H. Beeder, W. S. Autrey, George Baylor, T. P. Cunningham, R. J. Fisher, L. C. Gilbert, C. J. Henry, Claude Johnston, T. D. Kern, R. H. Lee, B. B. Lewis, R. B. Rice, V. J. Roggeveen, J. A. Rust, D. O. Van Strien.

In accordance with its practice, in effect since 1959, Committee 24 canvassed the railroads during the spring of 1967 concerning their summer employment needs for engineering students. A brief but formal questionnaire was sent to the chief engineering and maintenance officers of the railroads of the United States and Canada requesting information about their requirements for the coming summer, as well as information about their program of the preceeding one.

There was a gratifying increase in the number of questionnaire returns for the 1967 season over previous years. This was no doubt largely due to the greatly increased demand for engineering graduates on the part of industry generally—an increase which will continue, in accordance with all prognostications, for a good many years to come. There is also a continuing increase in the number going on beyond the first degree into graduate work. These and other factors will result in a continuing scarcity of young engineers. The railroads are no doubt aware of this situation.

The following tabulation presents the results obtained from the 1967 questionnaire. Information concerning summer employment of student engineers as well as other college students in 1966 is also included. The number reported employed during the summer of 1966 and the number permanently employed are considered to be only an indication of the total that could have been reported, and the figures presented are thus only approximate.

1967 Summer Employment Program

	Number of Railroads
Offering employment through Committee 24	25
Offering employment but *not* through Committee 24	29
No employment available in 1967	18
Total return of questionnaire	72

1966 Summer Employment Program

Offering employment through Committee 24	16
Offering employment but *not* through Committee 24	17
No employment available in 1966	16
Total return of questionnaire	49
Number reported employed during 1966	1739
Number of these reported as having been employed previously	686
Number from summer employees reported as having been permanently employed	71

The committee thanks the railroads for their continuing encouragement and requests their cooperation in 1968.

Report on Assignment 5

Ways In Which Railroads Can Cooperative with Universities In Developing Research, Including The Revision of "Suggested Topics For Study and Research On Railroad Subjects"

H. E. Hurst (chairman, subcommittee), R. H. Beeder, A. W. Cooper, T. P. Cunningham, R. P. Davis, R. J. Fisher, L. J. Hoffman, W. H. Huffman, C. Johnston, W. S. Kerr, H. E. Kirby, H. R. Moore, R. D. Pedersen, R. B. Rice, V. J. Roggeveen, T. G. Schultz.

Your committee submits the following report of progress as information:

The committee reaffirms its confidence in the merit of appropriating $1000 in the Engineering Division Research Budget to continue the Student Research Grants.

Your committee also continues to seek a suitable means for making available a listing of student reports or theses on railroad subjects. One current report for which the AAR provided funds for its final preparation under a student grant is entitled "Influence Chart for Moments in Railway Rails" by G. C. Martin, produced at the University of Illinois under the guidance of W. W. Hay, professor of railway civil engineering.

With the recommendation that the assignment be continued, your committee also presents below a revised listing of "Suggested Topics for Study and Research on Railroad Subjects."

SUGGESTED TOPICS FOR STUDY AND RESEARCH ON RAILROAD SUBJECTS

Accounts and Statistics

1. Develop a set of standard methods, possibly with the use of a computer, which would produce figures to give a uniform means of cost comparison. One of the difficulties in deciding on the type of equipment or the theoretical advantage of one system of maintenance over another is the problem of getting good cost figures on which to base an opinion. The ICC standards of accounting make it difficult to get actual cost figures on new methods. Each railroad tends to present its own ideas in the most favorable light. On many railroads, the efficiency of their particular operations is judged by a time study taken in a short time period, and does not take into account the long-range results or a monthly or yearly average.
2. Develop depreciation reserve accounting for the Internal Revenue Service.
3. Modify Interstate Commerce Commission reports to an IRS basis.
4. Report on the application of Depreciation Accounting Methods and the efficacy of their use since 1943.
5. Study the utilization of machine accounting, and computer programming to provide up-to-date cost data for maintenance and construction, etc.
6. Present and potential applications of computers to implement and control railroad operations, financing maintenance, etc.

Ballast

1. Evaluate desirable characteristics, economics involved, and realistic methods to establish stability, drainage, load-carrying abilities, durability, frictional characteristics, etc.

2. Determine effects of gradation and geometric characteristics (Particle Index) on shearing strength, density and compactability, on the frequency of reballasting, surfacing and lining, and life of ties, rail and track fastenings, etc.

3. Determine the effect of longitudinal forces on stresses in ballast sections.

4. Study or develop a relationship between compaction in ballast sections and uniformity of settlement under moving or dynamic loading.

5. Develop methods and equipment for study and evaluation of stresses in ballast sections; through the use of strain gages, pressure cells, etc.

See also Bridges.

Bridges

1. Economics of design and fabrication of welded wide-flange beams and welded girders fabricated with steel plates—this study to determine the economical thickness of steel plates to be used in the webs and flanges of such beams and girders of various span lengths to accommodate railroad loading. The topic might include some discussion on the possibility of using horizontal stiffeners on the outside of webs to improve the appearance of girder spans.

2. Economics of various types of ballast troughs for supporting railway track ballast on railway bridges, taking into consideration service life, cost of maintenance, and effect of the dead load of the troughs. The following types of ballast troughs are suggested for study:

a. Wrought-iron plates provided with waterproof covering protected by asphalt plank to resist abrasion by the track ballast.
b. Creosote-treated timber with galvanized steel fastenings.
c. Reinforced concrete slabs:
   (1) Precast slabs
   (2) Poured-in-place slabs

This topic could also include a discussion of methods for installing ballast troughs on existing railway bridges so as to achieve minimum interruption to railway traffic.

3. Fireproofing railroad bridges, methods and evaluation of economic factors involved.

4. The use of timber in railway bridges—including economics and development of chemical treatments to increase service life.

5. Develop impact formula for the design of ballasted and non-ballasted railway bridge structures of steel and reinforced concrete for modern loading.

6. The participation of floor and lateral systems in the stress-carrying capacity of the chords of steel railway bridges.

7. The design and adaptation of post-tensioned reinforced concrete for railroad bridges.

8. The effect of creep and relaxation of the tendons in the design of post-tensioned precast concrete slab and beam units for medium-span railway bridges.

9. The effect of increased axle loading on timber piles, caps and other treated timber bridge components.

10. The study of structural fatigue problems and related considerations in railroad bridges.

Buildings

1. Study design, materials and economies in using portable and semi-portable buildings, particularly prefabricated, at terminals and stations where flexibility due to changing needs is paramount.

2. Evaluate the use of infra-red rays or other new means of heating shops, warehouses, and other railroad buildings.

3. Study of structure designs, including high platforms, to accommdoate 150-mph or higher train speeds.

Centralized Traffic Control

1. Develop economics of siding spacing and relation to traffic densities, etc., consider use of computerized studies to develop.

2. Developments and adaptation of TV monitoring to CTC operations, automatic train operations and automation potentials of TV monitoring.

3. Develop a computer program for simulating train operation to evaluate the economic aspects of CTC.

4. Study and develop a system for incorporating speed control as a part of present CTC systems.

See also: Computers; Operations; Signals.

Clearances

1. Study to develop an adaptation of electronic equipment and other devices to replace or supplement mechanical measuring devices on clearance cars and equipment.

2. Study the effect of high train speeds on clearance requirements.

3. Develop a computer program for establishing the routings for special heavy, or high-and-wide loads.

Communications

1. Report on microwave communication developments and the economic results of this mode of communication, now in effect on several railroads.

2. Evaluate the savings and safety benefits resulting from the use of radio communications for train movements and other uses, etc.

3. Report on the problems and solution of interference to signal and communication circuits resulting from high-voltage a-c transmission lines.

Competition

1. The position and role of the railroads in the current highway and waterway development programs, and in the development of metropolitan areas.

2. Truck and rail freight-haul costs. Determine the zones of distance where truck haul is cheaper to the shipper on the basis of tons shipped. It is generally considered that, for short hauls, the truck is cheaper, and also for less-than-carloads. For a given tonnage there must be a "break even" distance beyond which the advantage in costs is in favor of the railroads. A determination of this point should be of value to the shipper, if determined by a neutral, factual study of the problem.

See also: Costs; Legislation; Management.

Computers, Electronic

1. Develop a mathematical model for railroad operations to make a network analysis of an entire railroad system and subsystem components as an aid in managerial and supervisory decision making—yard locations, locomotive and equipment maintenance, size of car and locomotive fleets, etc.

2. Develop a universal computer-oriented language for railroad engineering computer programming—writing computer programs for typical engineering problems suitable for any computer and any railroad.

3. A proposed universally acceptable waybill brought up to date in view of modern electronic business machines:

a. State of the art in "Character Recognition."

b. Machine identification of magnetic or similar ink, type, face, etc.

4. Factors that will enter into computer solutions of the question of long, slow, few freights versus short, fast, frequent trains.

a. When is the optimum time to run a freight train?

b. Railroads lose business to trucks because they leave their terminals shortly after loading. Railroads frequently hold freight for a day. This is basically a topic in linear programming.

See also: Accounts; Centralized Traffic Control; Clearances; Crossings; Location; Management.

Costs

1. A restudy and revision of the "Yager Formula" of the AREA for determining the relationship and changes in annual costs of maintenance of way expense, due to changes in volume of traffic. This formula was originally determined during the federal control of railroads.

2. Make an up-to-date and more accurate determination of the relation between fixed and variable costs in the several systems of transport.

3. Advantages and disadvantages of leased or rented facilities, and equipment, versus railroad ownership.

4. Economics of standardization in railroad practices.

See also: Accounts and Statistics; Competition; Operation; Track.

Crossings, Grade

1. Develop the responsibility relationship of public versus railroads.

2. Economics study of grade crossing construction and maintenance.

3. Relative advantages and disadvantages of various types of grade crossing construction.

4. Trends toward greater public participation in crossing protection.

5. Improved means for railroads to obtain maximum participation in crossing elimination and protection by public bodies.

6. Establish a realistic basis for assessment of crossing expenses, i.e., the public, railroads, etc.; consider computer analysis.

Drainage

1. Effects of changes in land use on water runoff and drainage structure requirements.

2. Effects upon ballast, roadbed, and track maintenance.

3. Evaluate current methods and means of calculating runoff and waterway size requirements; adaptation of hydrologic formulas and data to railroad requirements; computer analysis.

Electrification

1. Problems and design considerations required by catenary systems used for "high-speed" electric-powered trains.

2. Adaptations of electric power to "high-speed" trains, and relative merits, etc.

Freight Stations and Freight Handling

1. Study materials and design of pallets and/or containers which will provide for freight handling by fork-lift trucks and similar equipment, reducing labor requirements.

2. Study the economy resulting from packaging goods on pallets or in containers which can be handled as units through distribution channels to retail outlets.

3. Study to determine what measures may be taken to reduce damage to commodities transported by rail and the cost of claims for such damage.

4. Study the desired flexibility characteristics for freight containers, etc., between different modes of transportation.

See also: Piggyback or TOFC.

Freight Traffic

1. New and changing sources of freight traffic and the engineering problems involved.

2. The economic aspects of jumbo cars; using cars as moving warehouses, eliminating stock inventories, etc.

General

1. Relationship of transportation facilities to city planning, development, and redevelopment.

2. Opportunities for solving railroad problems through research, government aid, etc.

3. Automatic and non-destructive testing and inspection devices.

Industrial Development

1. Railroad approaches and incentives to the development of industrial tracts.
2. Desirable types of industries for railroads.
3. Industrial plant location considerations and trends.
4. Right-of-way "air rights" developments and resulting engineering problems.

Legislation

1. Analysis of changes in restrictive railroad legislation in the various states, i.e., justification, arbitrary character, need for constructive changes, etc.

2. Progress in the consolidation of transportation forms under the Department of Transportation, and the development of a uniform national policy.

3. Study of railroad taxation inequities, and the relation to the community life, and requirements.

4. History of, and the character of government control of railroads and other forms of transportation.

5. Study of anti-trust laws or legal aspects of current mergers and competitive types of transportation.

Location

1. Review, revise, and develop more accuracy in all railroad engineering design and location criteria.

2. Economics of grade and line revision. Objectives: reduction in operating and maintenance costs.

3. Utilization of photogrammetry in construction and relocation of railroads.

4. Utilization of computer programs in evaluation of alternative locations.

Management

1. Planned allocations of resources for maintenance of way—budget forecast, revenue, and traffic factors, planning for steady base loads of work.

2. Investigate the advantages and disadvantages of broadening the deferred payment method to cover large expenditures for additional railroad plant and equipment. Conditional sales agreements with manufacturers are used to cover large expenditures for furnishing and installing various types of permanent facilities ,such as signals, car retarders, etc. Also, agreements with finance companies are used to cover leases of more expendable items, such as trucks and roadway maintenance equipment.

3. Study of the potential consolidation of railroad systems on a national basis and the problems involved, with suggestions for solving these problems.

4. Report on current progress of mergers, difficulties involved in consummating, methods used, and the computer potential for determining costs, etc.

5. Potential and current value of R & D programs for railroad managements.

See also: Competition; Computers; Legislation.

Materials

1. Study the economics of standardization.

2. Study the potential and use of plastics for railroad track construction.

See also: Costs.

Motive Power

1. Developments in diesel, electric and nuclear power, etc.

2. Optimum power potential and possibility of increasing efficiencies of locomotive units.

3. Diesel engine spark control problems, developments and potential solutions.

4. Fossil fuels versus nuclear fuel.

See also: Rolling stock.

Operations

1. Study and develop the ways and means to effect a reduction in transit time between origin and destination of freight rail shipments.

2. What are the economic and operation factors affecting fixed-consist, light-tonnage, through-freight-train operation between major terminals, i.e., Chicago to the West Coast, New York through St. Louis or Chicago to the West Coast, etc.

3. Study or evaluation of automatic train operation.

4. Rapid transit control system requirements.

5. Centralized railroad operations.

a. Recent developments, control and coordination centers, etc.

b. CTC

c. Car dispatching or distributing

d. Billing

6. Determine the effects on railroad capacity, operation and costs of varying geographical areas of the United States (for example, the short-haul, multi-terminal

operation of eastern railroads as contrasted with the long-haul, and few terminals encountered, by railroads of the West; also mountainous terrain as contrasted to flat terrain, etc.)

7. Develop more nearly exact measures of track and traffic capacity for railroads. The increasing traffic load on line-haul and rapid-transit facilities and the need for increased efficiency in the utilization of the minimum plant requirements make desirable an improvement in existing and cumbersome methods of computation. The adaptation of such new methods to computer solution should be included.

8. Improved methods to increase car and power utilization.

9. Computer analysis of transportation and operating problems.

10. Automatic identification and control systems.

11. Evaluate various types of transport as to their relative engineering and economic efficiencies for various specific functions.

See also: Computers; Costs; Freight Houses and Freight Handling; Traffic; Passenger Traffic; Piggyback; Rolling Stock; Weather; Yards.

Passenger Traffic

1. The role of railroads in commuter service resulting from the expanding suburban living trends.

2. Development of optimum usage and coordination of all forms of passenger service, including possible combination of terminals.

3. Location of passenger facilities.

4. The role of rail transportation in urban corridor and network developments.

5. Study and comparison of current "Mass Transit Authorities", i.e. BART, NYCTA, PATH, SCRTD.

6. High versus low platforms for high-density passenger traffic.

7. Fare collection automation and developments.

See also: Operations; Costs.

Personnel

1. Role of graduate students in railroad transportation.

2. Railroad requirements for technicians versus engineers.

3. Responsibility of railroads and methods of training college graduates in the various problems of the industry.

Piggyback or Trailers-on-Freight-Cars (TOFC)

1. Growth and advantages of TOFC operations.

2. Investigate the various types of piggyback and container transportation equipment and services now in use on railroads and determine which offers the greatest economic advantage, or recommend a new system which would have a greater economic advantage or potential.

See also: Freight Stations and Freight Handling; Operations.

Piping

1. Economic and technical aspects of various types of materials used for piping, including plastics.

2. Cathodic protection of underground steel pipelines and steel tanks, including methods for determining soil conductivity. Testing techniques and procedures to achieve adequate protection, etc.

Pollution

1. Railroad air pollution problems, developments and solutions.

2. Railroad water pollution problems, developments and solutions.

Rail

1. Study the flow of metal in rail. This could be an extension of the field of study developed by C. J. Code's experiments of inserting brass plugs in the head of a rail and observing over a period of time the change in the size and shape of these plugs due to the flow of metal in the head of the rail.

2. Develop a program to determine economical rail sizes. This involves developing a guide to judgment in the economic selection of rail for different traffic conditions.

3. Make a comprehensive study of the entire subject of rail life.

4. Rail-wheel contact stresses; changes resulting from heavier loads; rail size and wheel contour relationship, etc.

5. Rail shelling and corrugation, causes and solutions.

6. Rail stresses and instantaneous load measurements.

7. Field measurement of rotative and lateral slip, etc.

8. Economics of rail wear versus track maintenance for higher axle loadings.

See also: Track.

Roadbed

1. Report on the developments in improved stabilization methods (mechanical, chemicals, etc.)

2. Protection by moisture barriers (bitumens, synthetic polymers, and other additives, etc.)

3. Report on the determination of the passive resistance pressure of soils and the application to the design of flexible culvert structures.

4. Develop a soil analysis test for determining chemical additives to stabilize subgrade conditions.

5. Effect of pH factor in water on soil or subgrade stability.

See also: Drainage; Track.

Rolling Stock

1. Develop ways and means of improving the utilization of rolling stock.

2. Study the need for specialized freight equipment.

3. Report on the ultimate effect, including cost analysis, to be gained by equiping all railroad cars and equipment with roller bearings.

4. Study passenger car designs which will allow passengers to have more comfort and relax more easily.

5. Study and evaluate the cost of providing specialized freight equipment versus all-purpose freight equipment of standard design.

6. Report on the developments and solutions to the journal "hot-box" problem.

7. Report on the developments and trends in the designs of modern railcars and equipment for high-speed passenger service.

8. Report on the developments in equipment to reduce lading damage and provide "damage free" freight service.

9. Report on the work of up-grading equipment for changing traffic requirements versus new equipment acquisition.

10. Report on the development of optimum freight car sizes and configurations.

See also: Computers; Motive Power; Operations; Passenger Traffic; Piggyback.

Signals

1. Study the progress and potential for modernizing railroad signal systems by the application of transistors, solid-state circuits and miniaturizing.

2. Report on the reported savings obtained by the replacement of double tracks by a single track with centralized traffic signal applications.

See also: Communications; Centralized Traffic Control.

Ties

1. Study the economics of tie spacing. If the number of ties were reduced, it is possible that they might have to be tamped more frequently, but there would be fewer ties to tamp and less ties with plates and fastenings to maintain, etc.

2. Study tie renewal programs by the out-of-face method as compared with individual renewals. Determine what percentage of a tie's total expected life can be economically thrown away in order to make renewals with specialized tie gangs.

3. Report on the development of concrete ties and fastenings and the economic factors of concrete or other tie materials versus wood.

4. Study the effect of frost-heaving on the design of concrete ties.

See also: Track.

Terminals

1. Report on the developments in highway–railroad transfer service.

2. Study the potential effects of intermodal integration of terminal facilities.

3. Report on the economic and other factors involved in the location of terminal facilities; consider the effect of high-speed train operation.

Track

1. Study the effects and cost of railroad curvature on location and operation. The increased resistance due to curvature, the causes thereof, the cost, and the effects of curvature on operation under modern conditions have been the subject of much contradictory evidence and argument. An impartial study could aid in establishing acceptable principles.

2. Investigate the status of the railroad track structure in the light of current and future types of motive power, speeds, axle loading, equipment, and materials.

3. Study the economics of deferred maintenance practices.

4. Make an evaluation of track conditions and maintenance efficiencies.

5. Develop the various considerations involved in connection with design changes required for high-speed train operation.

6. Report on track stability and support problems associated with high-speed developments. Consider computer approaches to program dynamic responses or resiliency of track structures.

7. Report on the development of cars and equipment used for testing track riding characteristics, etc.

8. Develop a simple method for determining modulus of track elasticity.

9. Develop a simple method of determining quantitative measure of compression or tension in CWR.

See also: Ballast; Costs; Operations; Rail; Ties.

Tunnels

1. Report on the ventilation of long railroad tunnels.

2. Report on modernization requirements and methods of obtaining increased clearances.

3. Study the design problems and requirements of single- and double-track tunnels to accommodate high-speed (150 mph plus) operations.

Unit Trains

1. Report on the developments in unit-train operation.

2. Study the economic aspects of unit-train operation and possible potentials.

3. Study the possibility of increasing tonnage in unit trains by elimination of couplers between cars.

4. Report on possible design changes desired or required for unit-train operations.

Vegetation Control

1. Make an evaluation of vegetation control methods, i.e., mechanical, chemical, etc.

2. Investigate weed-control problems and the associated relationship with public bodies.

Weather

1. Study the effect of sub-zero weather, snow and ice on operations; consider equipment and lubrication problems, etc.

2. Report on the effects of temperature on rail, joint bars, wheels, and axle breakage and the problems arising therefrom.

3. Report on the effect of weather on overall speed of trains, on track, and traffic capacity.

4. Study the effects of weather on the speed of car movements through yards and on yard locomotive capacity; this would include a study of tonnage ratings with the new types of motive power.

5. Report on the variations in regional operating costs and problems due to weather.

6. Study the problems involved in shipping various commodities, liquids, etc. Consider the effect on capacities, costs, etc.

See also: Operation; Location.

Yards

1. Study the factors influencing location and design of freight classification yards—mathematical models, systems design, instrumentation.

2. Study interior illumination of railroad-yard control towers, with emphasis on the elimination of glare or reflected light from windows.

3. Study the possible ways of improving the illumination of large railroad yards.

4. Report on the use of radar and similar equipment for checking the operation of freight classification yards; consider the relative effects of the factors involved in developing efficient hump yard operations.

5. Report on developments in railroad yarding methods.

See also: Computers; Buildings; Operations; Weather.

Report of Committee 32—Systems Engineering (Formerly the Special Committee on Systems Engineering)

°L. P. Diamond, *Chairman*
°W. R. Bjorklund, *Vice Chairman*
°R. C. Gilbert, *Secretary*
°A. W. Polich
°H. R. Williams
°G. L. Nichols

°R. G. Wilhelm
°J. F. Davison
°Dr. H. N. Laden
R. S. Allen
E. R. Andrlik
R. W. Bailey
S. H. Barriger
F. T. Berry
R. J. Berti
E. Bond
W. E. Brakensiek
A. P. Campbell, Jr.
H. L. Chamberlain
R. D. Combs
L. F. Currier
Dr. R. P. DeCamara
A. V. Dasburg
R. L. Dean
R. Dirvonis
W. E. Dowling
W. J. Drunsic
R. L. Ealy
F. C. Edmonds
F. D. Free, Jr.
E. H. Fisher

A. J. Gellman
R. W. Gerstner
L. F. Grabowski
R. W. Holt
R. P. Howell
J. R. Iwinski
M. W. Krug
R. H. Knittel
A. S. Lang
A. D. M. Lewis
J. F. Lynch, Jr
A. B. Merritt, Jr.
G. F. McGlumphy
K. S. Niemond
J. A. Penner
B. H. Price, Jr.
T. H. Seep
R. A. Stane
J. J. Stark, Jr.
L. L. Tameling
T. W. Toal
R. E. Vander Klipp, Sr.
E. N. Wilson
T. D. Wofford, Jr.
Committee

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 32.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Define and illustrate systems engineering concepts, developing a manual of specifications for their application to railway engineering.

   Progress report, presented as information . . . . page 298

2. Document present computer assignments of all AREA Committees—indicating their relationships in overall systems—with identification of potential for expansion.

   Progress report, presented as information . . . . page 301

3. Develop specifications for engineering administrative systems such as PERT, CPM Time and Cost.

   No report at this time. The committee is gathering information on applications of PERT, and allied network control systems, to repetitive operations as well as to one-time projects. Included in the investigation are factors of time, resource allocations, cost, and the mathematical models employed to coordinate them in the practical case.

4. Define and specify all elements in the engineer-computer interaction, promoting simplified and expeditious computer usage by the engineer in all his functions.

   Progress report, presented as information . . . . page 304

5. Promote computer usage by railway engineers through demonstrations, seminars, and programs of instruction by leaders in the field.

   Advance report entitled, "Project HISTEP" appears in Bulletin 608, September–October 1967, beginning on page 102.

   Advance report entitled, "Computer Service By Time-Sharing" appears in Bulletin 608, September–October 1967, beginning on page 96.
   Report entitled, "Introduction to QUIKTRAN" .... page 306

6. Liaison with the AAR Data Systems Division for engineering applications, including study of the operation of its computer center at Washington, D. C.

   No report at this time. Initial contacts involved arrangements for memberships in the Data Systems Division of all members of the committee. Active contacts were to be made with various Data Systems Division committees for specific projects. Plans are to propose continuation of these arrangements with the Management Systems Department, AAR.

THE COMMITTEE ON SYSTEMS ENGINEERING,
L. P. DIAMOND, *Chairman.*

AREA Bulletin 610, December 1967

Report on Assignment 1

Define and Illustrate Systems Engineering Concepts, Developing a Manual of Specifications for Their Application to Railway Engineering

A. W. POLICH (chairman, subcommittee), R. J. BERTI, A. P. CAMPBELL, JR., A. V. DASBURG, R. P. DECAMARA, R. DIRVONIS, W. E. DOWLING, W. J. DRUNSIC, E. H. FISHER, A. J. GELLMAN, J. R. IWINSKI, H. N. LADEN, A. S. LANG, J. F. LYNCH, G. F. MCGLUMPHY, B. H. PRICE, JR., E. N. WILSON.

Your committee submits, as information, the following initial report which will serve as an introduction to the subject. Detailed reports will subsequently cover the items developed herein.

To explain Systems Engineering we must consider that in our society of creative technology, it has become increasingly important to reduce the time lag between the appearance of needs and the creation of systems to satisfy these needs. It becomes important then to create a model, or methodology, which technically oriented people can utilize to solve complex systems-type problems. Any model, methodology, or system which results in an acceptable solution to a particular problem or family of problems is, of course, a successful model, methodology or system.

It is important, however, to recognize that when past methods of solution fail for other types of problems, that some general model does exist which can give direction to further effort toward a satisfactory solution. Many times a problem-solving technique which has been successful in the past will not yield acceptable results when applied to more complex problems. This can happen, for example, when interactions between components of a system are not given proper consideration. The individual component solutions may be accurate, but the interactions between the components which make up the entire system may alter the characteristics of the overall result. We must learn, therefore, to think in terms of the entire system and of the final results desired in the overall picture.

In order to develop a methodology for solving these complex problems, it is necessary to generalize to include as many different types of systems and problems as possible. A common denominator must be found which will allow a systematic approach to all problems.

The most basic problem-solving technique known is the "scientific method" and it forms the basis for the systems approach. This technique is elementary in nature and provides an organized approach to solving even the more complex problems.

The systems engineering approach to problem solving, then, consists of the following functions:

1. Definition of the problem
2. Selection of objectives
3. Synthesis of systems
4. Systems analysis and selection of the best alternative
5. Communication

An examination of each of these functions may help to explain the systems engineering process.

1. Definition of the Problem

This function is perhaps the most difficult, since it forms the foundation for the functions which follow. An inaccurate definition may result in a perfectly valid solution but for the wrong problem!

The problem definition must contain an investigation of the environment, considering such items as:

a. The state of technology
b. The natural environment (climate, physical properties, supply of raw materials, etc.)
c. Organizational policies
d. Economic conditions
e. Human factors

Problem definition must consider what form of input is available and what form of output is desirable. Other considerations might include the urgency of the problems, the degree of risk that management will accept, physical limitations on size, the frequency with which the problem occurs, etc.

2. Selection of Objectives

Objectives are the criteria or yardsticks against which the alternatives are evaluated. Objectives also serve to measure where we are in the solution process.

3. Synthesis of Systems

Synthesis is the creative process which proposes solutions to the problem. All known alternatives, including the present system, if one exists, should be listed regardless of how impractical some may appear. Various techniques have been developed to aid in this step such as "brainstorming", "permutating", "sub-dividing" and others.

4. Systems Analysis and Selection of the Best Alternative

This function provides for obtaining the best solution by comparing the various alternatives to the objectives. It may be necessary to revise certain objectives to obtain a workable solution. The various decision-making tools may be utilized here. These may include, among others:

a. Simulation
b. Linear programming
c. Network analysis
d. Statistical probability
e. Game theory

5. Communication

Since the systems problems may concern many departments of the railroad, such as engineering, operating, purchasing, financial, management, and others, communication with these groups during all stages of the solution will probably be necessary. Feedback loops are important to be sure that proper information flows are achieved.

When the systems engineer is satisfied he has the best solution to a systems problem, he must sell management on his idea. A well-prepared systems proposal may do much to narrow down the area where judgment must be employed, but there will still be that which must be evaluated on a qualitative basis. It is part of the job of the systems engineer to sell these ideas to management so that eventually the results may be shown to be good for the railroad.

Finally, feedback after implementation of the system is important to provide for continuously evaluating the system, both against the original objectives and any changes in objectives.

Example

For illustration, a hypothetical railroad engineering application would be as follows. Assume that it has been established that our need is to find the best economical allocation of money, work gangs, and equipment to maintain track based upon available resources each year. Economics of various railroad properties could lead to different specific answers. The governing system would be the same for all railroads. Such a system might include:

a. Track inspection using an appropriately designed roadway inspection vehicle gathering data on several track quality variables.
b. Automated track inspection with computer programs to process and convert roadway inspection recordings into numbers and to perform quality-control analysis with them.

c. Models of relationships between track conditions and maintenance expenses developed by computer programs to forecast and best allocate maintenance money and effort.

d. Through collaboration of systems engineers with engineering specialists in the fields of ballast, ties, rail, bridges, structures, signals, communications, and with the aid of the above computer programs, it would be possible to develop the details of optimum amounts of materials, work locations, maintenance equipment types, work gang size and organization, and time schedule to form the annual track maintenance program.

Report on Assignment 2

Document Present Computer Assignments of All AREA Committees—Indicating Their Relationships in Overall Systems With Identification of Potential for Expansion

H. R. Williams (chairman, subcommittee), E. R. Andrlik, R. W. Bailey, S. H. Barriger, F. T. Berry, R. J. Berti, W. R. Bjorklund, L. F. Currier, J. F. Davison, L. P. Diamond, R. L. Ealy, F. C. Edmonds, L. F. Grabowski, R. P. Howell, M. W. Krug, J. A. Penner, T. H. Seep, L. L. Tameling, T. W. Toal, R. E. Vander Klipp, Sr., T. D. Wofford, Jr.

Your committee submits the following report of progress in documenting the status of the assignments of those AREA committees that have computer assignments. At this early date in the study, it is too early to include information as to the assignment relationships and potential for expansion. As the various standing AREA committees progress their respective studies, we will analyze and document the assignments illustrating their relationships in the overall systems.

Committee 11—Engineering and Valuation Records.

The committee's assignment in computers is entitled, "Application of data processing" and pertains to those studies in data processing techniques in the engineering and accounting fields.

In 1965 the committee prepared and presented a special report on a system of accumulation of property accounting data through use of routine accounting information reporting. This appears in the Proceedings of the AREA, on page 197 of Bulletin 596 dated December 1965.

Earlier, Committee 11 had completed a study and prepared a special report on data processing of construction reports—engineering phases. This report outlines a system of generation and accumulation of engineering and accounting data for construction projects. It is, basically, engineering oriented and deals with activity relating to the acquisition, classification, and processing of source data needed for the establishment and perpetuation of engineering and property records.

Currently a survey and special study have been completed relating to the specifications and procedures and will be offered as a guide for a system design covering property purchased and accounted for in R&E Account Classification No. 37, Roadway Machines. Information on this assignment is included in the report of Committee 11 in this Bulletin.

Efforts of this committee are also being directed toward the development of data on construction project cost accumulation and associated physical data.

Committee 16—Economics of Railway Location and Operation.

This committee's computer assignment pertains to the potential application of electronic computers to railway engineering and maintenance problems in research, design, inventory, etc.

Since creation of the Special Committee on Systems Engineering, Committee 16 has re-examined its objectives. It has been concluded that the general course of activity which has been pursued in recent months should be continued.

The object of the subcommittee's investigation is "potential" rather than actual applications. However, the investigation of potential applications implies a knowledge of current actual applications. Therefore, the subcommittee decided to dimension the current state of the art before searching for additional new applications. This endeavor took three avenues: (1) What is the current state of computer applications by railroad engineering organizations? (2) What is the state of engineering applications outside of the railroad industry? and (3) What is the state of computer graphics?

Accomplishments to date are as follows:

1. The programming Techniques Committee of the AAR Management Systems Division has undertaken to collect computer programs of special interest to the railroad industry. These are presumably programs which are somewhat unique in the program or in the method of applying computer technology to the functional activity involved. Copies have been obtained and those of interest to railroad engineers are being studied.
2. The subcommittee has invited manufacturers of computer hardware to meet with the committee for the purpose of the looking at a broad range of applications of computer technology to the civil engineering field.
3. The committee has done a cursory literature search for information about computer graphics. A paper by David Prince, in the Proceedings of IEE, Vol. 54, No. 12, December 1966, pp. 1698–1708, is a comprehensive report on computer graphics according to the subcommittee.

An abstract indicates that the above-mentioned paper:

"Reviews the history, concepts, state-of-the-art, and future directions of the use of man-computer graphics for computer aided design. Computer-aided design is based on a real-time graphical dialogue between the man and the computer in which the man draws on a display by means of a "light pen" or other input device. The computer "understands" the picture, makes calculations based on it, and presents the results pictorially to the user for his approval or revision. This man-computer graphical conversation has been made possible by recent advances in the speed of the digital computer, timesharing programming, computer-driven display technology, and graphical input devices. The light pen is the most commonly used graphical input device, but keyboards, joysticks, flat matrix arrays, and other devices are also used.

"The programming state-of-the-art is a limiting factor in the implementation of graphical computer-aided design; much work remains to be done in systems programming, efficient time sharing, list structure concepts, file organization, and memory protection. A number of experimental equipment configurations in use in various laboratories are cited and the hardware state-of-the-art is reviewed.

"Several experimental and productions applications of computer-aided design evolved in a large aircraft company are described and illustrated by display photographs. These applications relate to structural analysis, dynamics, information retrieval, accounting and numerical control tape preparation.

"For the future, advances are required in improved man-computer communication, techniques to permit the operation of displays at great distances from the central computer, and methods of inputting existing drawings into the computer in a meaningful form."

Committee 28—Clearances.

Committee 28 has a computer assignment pertaining to new methods and electronic devices for recording measurements of clearances of structures along right-of-way and overall dimensions of cars and loads in yards and at interchange points, looking to the possible use of computer program for routing high and wide loads.

Late in 1967 Committee 28 requested the Special Committee on Systems Engineering to handle this assignment. The request was made to the latter on the following basis:

"By a majority vote of 90 percent, with over two-thirds of our members voting, Committee 28—Clearances, has approved the following: Recommend to the Special Committee on Systems Engineering that they develop specifications and procedures for computerizing clearance diagram and weight restriction information for input of clearance requests and output, suitably monitored, on routing and granting clearance for excessive dimension and/or weight shipments, collaborating as necessary or desirable with the Mechanical Division, AAR, and the Operating-Transportation Division, AAR, as well as with appropriate committees of the Engineering Division, AAR."

Further information will be available on this matter early in 1968.

Committee 30—Impact and Bridge Stresses.

This AREA standing committee has an assignment pertaining to electronic computers.

In 1959 the committee utilized a computer program to calculate moment and shear tables for moving loads on simple spans. In subsequent years the committee selected railway equipment each year for which rating tables have been prepared. These tables were distributed to chief engineers of Member Roads. In 1964 a new computer program was written in FORTRAN. A basic program has been developed to calculate stresses in members of a truss span subject to moving loads. It is planned to expand the program to handle rating of truss bridges and to develop a similar program for girder bridges.

Report on Assignment 4

Define and Specify All Elements in the Engineer–Computer Interaction, Promoting Simplified and Expeditious Computer Usage by the Engineer in All His Functions

R. G. Wilhelm (chairman, subcommittee), R. S. Allen, W. R. Bjorklund, H. L. Chamberlain, R. D. Combs, L. F. Currier, W. E. Dowling, W. J. Drunsic, F. D. Free, R. W. Gerstner, R. C. Gilbert, J. R. Iwinski, R. H. Knittel, A. D. M. Lewis, K. S. Niemond, B. H. Price, Jr., R. A. Stane, J. J. Stark, E. N. Wilson, T. D. Wofford, Jr.

An engineering department of a large company establishing a computer facility faces several challenges, such as scheduling of company computers and available manpower. The department then has to evaluate and choose among several alternates. Factors for consideration are:

1. Costs—The system has to be economically justifiable regarding quantity and quality of work.

2. Manpower—Different systems would impose different requirements on engineering personnel.

3. Computer Growth—It must possess potential for gaining experience and knowledge about computers in general. It must help teach the engineer that it can solve his problems efficiently and educate him to this as soon as possible.

4. Software—Personnel must become familiar and trained in the use of the FORTRAN language and new problem oriented languages (P.O.L.), such as COGO and STRESS.

5. Physical Accessibility—Engineers should be able to interact with the computer, whether running problems or analyzing results.

6. Potential for Expansion—The system must possess the capability for expansion within the initial system or to another system.

7. Hardware Considerations—The systems to be considered are:
   a. Company computer facilities
   b. Small scientific computer system for department
   c. Service bureau operation
   d. Time-sharing system or computer utility.

8. Time—Time itself is still another consideration, such as delivery delays for hardware, delays to getting the system working, the initial step of developing programs, and finally the delay in using the system or considering turn-around time.

The next step is to consider the hardware systems mentioned in Item 7 above in terms of the other factors. One of the problems in considering company facilities is that machine time is not always available on an "as needed" basis. Also, like any service bureau operation, it offers little man-machine interaction. However, the advantages and disadvantages are mentioned here:

A—Department Computer

Advantages:

1. Small scientific computer—Low cost when compared to larger systems.
2. Located in office.
3. Many software programs available.
4. FORTRAN available.
5. COGO and other P.O.L.'s available.

Disadvantages:

1. Many large problems cannot be solved.
2. Delivery time delays.
3. A larger system to initially learn, requiring special people.

B—Service Bureau

Advantages:

1. FORTRAN and P.O.L. available.
2. Can use right away.
3. Varying costs on jobs.

Disadvantages:

1. Turn-around time questionable.
2. Machine not in office, offering little man-machine interaction.
3. Delivery and pick-up considerations.
4. Program development complicated by not having direct access for debugging.

C—Time-Sharing

Advantages:

1. Relatively low cost.
2. P.O.L.'s and FORTRAN available.
3. Programmer interaction for debugging or can also batch process.
4. Subscribe almost immediately.
5. Terminal present in office.
6. Common library available to many users.

Disadvantages:

1. Available only during certain hours.
2. Some delays in operating system.
3. Limitations as far as man-machine interaction and computer training are concerned.
4. Loss of data could result.

Therefore, time-sharing seems to possess the best method for implementing an initial computer system within an engineering department. However, constant re-evaluation must be continued as development occurs. A small computer with a time-sharing capability to a larger system may be the ultimate answer.

There are three main areas to be considered for training personnel. One, the computer manufacturer offers training on his own property or in many cases will even conduct classes on the user's property. All types of manufacturers' literature make good training aids. Two, many other sources of training exist, such as the American Management Association, correspondence, and program instruction courses. Universities and other institutions offer many courses and seminars in computer technology. Finally, intra-company training should be considered whether it is "on the job" or "classroom" training. Many companies offer training for clerks, foremen, supervisors, mid-management and higher management within the company. Certainly, one or all of these sources should be explored where growth in technology is demanded.

Report on Assignment 5

Promote Computer Usage by Railway Engineers Through Demonstrations, Seminars and Programs of Instruction by Leaders in the Field

J. F. Davison (chairman, subcommittee), W. R. Bjorklund, R. D. Combs, R. L. Dean, L. P. Diamond, F. C. Edmonds, A. J. Gellman, R. W. Gerstner, R. C. Gilbert, L. F. Grabowski, R. W. Holt, R. H. Knittel, A. D. M. Lewis, A. B. Merritt, K. S. Niemond, J. A. Penner, T. H. Seep, L. L. Tameling, R. G. Wilhelm.

Introduction to QUIKTRAN

By R. G. WILHELM
Systems Analyst, Engineering
New York Central System

A new approach to man-machine computer interaction is QUIKTRAN—a symbolic programming language very much like FORTRAN. It has FORTRAN's characteristic of facilitating problem statements and programming for scientific and engineering problems expressible in mathematical form. The term QUIKTRAN is somewhat ambiguously, but very appropriately, used also to designate an organization consisting of (1) a man, (2) a communications terminal equipment for sending messages to a computer, (3) communications links to and from a remote computing facility, (4) the computing apparatus itself, (5) a communications terminal for receiving messages from a computer (the terminal may be a sending-receiving device), (6) the QUIKTRAN language, (7) certain formalized procedures of terminal equipment operation, and (8) "software" resident in the computer system for understanding QUIKTRAN and servicing programs presented in this language.

The language was named QUIKTRAN because the computer servicing take place with little or no delay for queuing up and waiting for completion of service to earlier customers. The computer software permits the interlaced time-sharing of a computer among a number of simultaneously competing terminals, each of which gets exclusive access to the computer for a very short burst of time only.

The QUIKTRAN hardware consists of:

(1) Magnetic Disk Storage Unit to be used for the permanent retention of users' programs.

(2) Magnetic Drum Storage Unit to be used for temporary storage of user's programs.

(3) Six Magnetic Tape Units to be used for reading and writing of magnetic tapes generally used to hold intermediate results in processing and for logging system transactions.

(4) Communication Control System to be used for control of communication links used in sending and receiving data.

(5) Two Disk Storage Drives connected to the communication system for use during batch processing.

(6) Data Set, a modulation–demodulation unit, for connecting the input/output terminals to the communication line to the computer.

The system provides concurent access to the computer for approximately 50 remotely located terminals. QUIKTRAN is compatible with most FORTRAN IV processors in that it contains essentially a subset of FORTRAN IV. However, it is augmented by a specialized set of operating statements, plus testing and debugging statements. The user may communicate in a statement-by-statement basis called "conversational" or "on-line" manner. He may choose alternatively to use the "batch" or "off-line" mode in which the basic input is an entire program (instructions and data) through a card reader and/or in conjunction with the terminal.

This time-sharing system has an advantage over other systems because of relatively low cost, its growing potential, and software availability. The fact that most engineering program development today is done in FORTRAN is making many additional programs available in the QUIKTRAN library. This is an added incentive to use the system. The cost of such a system breaks down as follows:

Description	*Cost/Unit*
I/0 Terminal Device	$ 87.50/month
Card Reader (Optional)	$253.00/month
Processing Unit—Plan A: 0–5 hr/month	$125.00/month
5–75 " "	$ 11.00/hr
75 + " "	$ 9.00/hr
Minimum Library Space (memory and some routines)	$ 60.00/month
Data Set Device—translates typewritten impulse to voice grade line	$ 27.00/month

Thus, for approximately $300/month, an engineering department can have access to a computer.

One Company's Experience

Since the installation of QUIKTRAN by one company training of personnel in its use has been and will be a continuous process. This cannot be emphasized enough. FORTRAN IV program instruction courses have been distributed to some engineering people, though it is not the department's intent to make programmers of engineers. Today, there are about 35 programs that have been written by members of the engineering department. Included with the system are common library programs to which any user has access.

Inquiries about the prospects for use have been made by other departments, such as the Marketing and Mechanical Departments. Some use already has been made of QUIKTRAN within the Mechanical Department. It has obtained an I/O unit of its own and is sharing the Engineering Department's time. Sharing time with other departments is becoming more of a reality. However, the other departments do not want to compete with the company's Computer Services. Analyzing operating administration regarding budgets, statistics and forecasting is yet another area for computer use and is presently going on in a small way.

The Engineering Department has been satisfied with the system in general. The following advantages are obtainable:

(1) Interaction between man and machine—namely, programmer interaction and diagnostics, such as line-by-line debugging.
(2) Allows programs up to 400 statements long—a good feature compared to other time-sharing systems which do not have this capacity.
(3) The console is present in the office in lieu of going elsewhere to have access to a computer.
(4) The software is compatible to FORTRAN.
(5) Time-sharing is a growing environment.

Of course, there are some disadvantages:

(1) There seems to be a great deal of delay time on occasion.

(2) Presently, the service is limited to 12 hr/day, 5 days/week.

(3) More library space above the minimum, ¼ million characters, requires more money.

(4) The common library programs are not documented to complete user orientation.

(5) The present open-shop policy of not scheduling is questionable for any indefinite amount of time.

However, QUIKTRAN and computers in general are not a panacea. There will be many "one-time" problems that will never reach the computer stage, but perhaps parts of these problems can be computerized. Nevertheless, the picture ahead is bright regarding computers and the engineering department.

Use of Computers in Solving Problems of Railroad Engineering*

By R. A. STANE

Construction Engineer, Coast Lines
Atchison, Topeka & Santa Fe Railway

The computerization of railroad engineering problems has attained a high degree of sophistication in the third generation of giant computers for massive problem solution, together wi.h a more personal computer that converses with the engineer by means of a typewriter throughout the computation and produces real time solutions.

Certainly, no attempt should be made to program all of our engineering problems and likewise, all problems for which programs are available should not be solved on the computer as it is a very expensive instrument. On the other hand, all too often problems occur that have been programmed and should be computerized but are done manually simply because of the skepticism of those of us who do not realize the economies in time and drudgery that may be derived. The pressing problem of the day, even more than further program development, is the computerization of the engineer, and this may be accomplished by exposure to program use or through groups such as this. The personalized computer is a persuasive tool in this respect and, hopefully, it will become more available in the near future.

It is not the intent to create here a compilation of engineering programs but rather to illustrate how a small sample of them might be used under job conditions. There are many similar programs known by various names which do each job in a somewhat different way. However, this paper will be confined to those in Santa Fe's library.

Let the illustration be a hypothetical railroad relocation proposed in a setting of rugged terrain. To create a situation as nearly real as possible, let the job be done by an engineer who is typically highly skeptical, but willing to give the computer a try.

The first problem is statistical and has to do with proving necessity. Volumes of historical operation cost data are accumulated for extrapolation into the future by means of curve-producing mathematical equations. There are many equations that may be developed, but the development of even the most simple of them is a tedious job to the point that the first curve, fitting even fairly close to the data, is likely to be accepted. The highly skeptical but willing engineer merely lists his data on a simple input sheet and turns the equation development over to a program called TREND which will produce not only linear, exponential, and logarithmic equations but will also indicate the equation most suited to the problem. The end results are a better prognostication by reason of a better curve and a more economical use of the engineer's time.

So as to progress this hypothetical project, necessity is proven and the problem moves to its next stage where proposed lines are located on quadrangles covering the area and center-line profiles are drawn on the various lines. At this point the still skeptical engineer temporarily discards his profile scales, symbolic of the laborious tasks of yesterday, and merely codes the profile elevations and subgrade control points and turns the job over to LESEC, a program that will return grading

* Paper presented before the Third Regional Meeting of the American Railway Engineering Association, Dallas, Tex., November 7, 1967.

quantities in cumulative totals. Benches and berms will be located internally, and any number of grade lines may be examined along a given center line without recoding the profile elevations. Those who have experienced the tedium of profile scaling for quantities need not be told that the engineer, backed by the computer, will make a more thorough search for the right grade line.

At this point necessity has been proven and a reasonable estimate of cost may be made, but will the effect on train operation warrant the expenditure?

It has been the Santa Fe engineers' experience that management is interested in not only the train operation across the relocated railroad, but also in its effect across the district. The possibility of converting time saved to additional tonnage on trains maintaining current schedules is a part of that effect. Trains of present and future configurations become a part of the problem, and so does the development of acceleration and retardation curves for those many configurations. This single task should cause even the most skeptical engineer to look to the computer for a way out. He would find it in TIMFL, along with many fringe benefits. Existing and proposed track grades, curves, and slow boards are coded on track sheets, and trains of all likely configurations are coded on train sheets. TIMFL will respond with detailed train performance, including fuel consumption. Trailing tons will be caused to increment internally to answer the increased tonnage question. In actuality, the project would not be put to the expense of coding the existing track, as a model of the entire railroad would have been maintained on magnetic tape or disks for operation problem solution.

So as not to discontinue the project at this point, the improvement in train operation justified the expenditure.

The relocation area is flown for stereo' photo coverage and a refined contour strip map is produced. The proposed line is plotted on the strip map and a more accurate profile is taken off. Again, LESEC is used for more realistic grading quantities, and because of the ease of recovering yardage while manipulating grades, the best grade possible is found and the engineer destroys his profile scales.

Next is the task of putting the line on the ground. Control points are placed in the field by measuring from objects recognized in the photographs. Sights are erected, but because of the terrain, one is seldom visible from another. A hill top network is staked having vantage points from which the line control points may be seen, and a transit-electro tape survey is run over the network which includes side shots to the line points. Line points may then be mathematically tied together by a series of oblique triangles or by ordinate and coordinate calculation.

Rather than hand-calculate his network, the not too skeptical engineer turns to BLINE through a simple code sheet and he receives a detailed ordinate and coordinate display of his network, with bearings and distances along his proposed centerline control points.

All of the control points are either on tangent lines between curves or are on semitangents of curves. ALINE, using data supplied by BLINE and curve data provided by our engineer, returns a complete alignment with engineers stationing and deflection angles around all curves and spirals. There is nothing left for the engineer to figure.

The alignment is staked and bench marks are established along the line in preparation for cross-sectioning for construction. This is done without the aid of a computer, but rather than hand-calculate subgrade elevations our no longer skeptical engineer uses GRADE, a routine stolen from LESEC. GRADE asks only for slopes, stations at grade breaks, and lengths of vertical curves, for which it returns grade sheets complete in every detail for permanent record along with subgrade elevations at all stations and half stations where requested. Later, it will provide similar sheets showing base-of-rail elevations.

It is fortunate that our engineer has gained confidence in the magic of the computer or he would not tolerate the next deviation from the laborious but tried and proven cross-sectioning procedures.

With tongue no longer in cheek he employs the code sheet of XSECT whose documentation tells him to show his height of instrument above sea level and not to figure the cuts or fills but to merely enter his rod readings over the distances across the section. Otherwise, he must concern himself only with finding the catch points so that they may be staked. Subgrades are not entered on the cross-section code sheet as the computer uses GRADE as a subroutine for their calculation. XSECT code sheets are submitted to the computer for quantity calculation and a print-out of cross sections showing cuts, fills, and subgrade. XSECT is versatile in that it will accept not only rods but cuts and fills or even ground elevations, and it may be caused to display the sections in cuts and fills or in ground elevations. Our engineer's faith is shaken, however, when the computer points out all slope stakes set incorrectly in the field.

Cross-sectioning, therefore, is turned over to a junior engineer, and our engineer undertakes land ties which necessitate the location of section corners lost in the rugged, timbered terrain. On finding each corner, an accurately measured random line wanders around the trees in the general direction of the next corner. Each corner, when found, is tied in to the random line and our engineer codes a record of his survey on the input sheets of CLOSR. With some misgivings, the code sheet is passed on to the computer which returns a display of all transit point and corner ordinates and coordinates, bearings and distances along the section lines as determined by the random line survey, followed by an adjusted bearing and distance listing eliminating the closing error. It includes the area enclosed by the section and then confirms our engineer's suspicions by displaying for permanent record a measure of the inaccuracy of his field work.

Let the project progress to the construction planning stage.

Bar graphs and arrow diagrams are two universally used planning tools and both are very satisfactory. However, the latter must be used for project scheduling in order to demonstrate the advantages of a program called PLAN, Santa Fe's version of CPM, which stands for Critical Path Method—a method not so universally accepted as its mechanics are not usually understood. Acceptance of the bar graph is of long standing for the simple reason that its mechanics are easily learned; it is perspicuous, and it is even possible to determine the critical path but not without considerable analysis. An arrow diagram, on the other hand, may be produced with less effort, but by itself, it is not as graphic as is the bar diagram, and until the critical path across the diagram has been found, it is not too meaningful. Let us say that the engineer is called upon to produce the path in order to place a reasonable time of completion on the construction and, as it is likely that it would be more simply found on the arrow diagram, the diagram is developed. Certainly, the most difficult part is in the development of the diagram, and they have a way of becoming extended and complex, but the most trying part is to find the elusive critical path, particularly with portions of the job working five, six, and seven day weeks.

Fortunately, our engineer decides to give the computer another chance, and he simply copies the numerical notations of his diagram on PLAN's input sheet, again passes it on to the computer and receives a display of the critical path with commencement and completion dates of each job on the path and a secondary path as well, and this display comes without criticism.

At this point we leave our engineer consoled and contemplating a less complex future reusing LESEC with center-line profiles for contractor's monthly estimates and an easily revised arrow diagram coded for PLAN reruns for job management and monthly reports.

Although the project is hypothetical, the trepidations of our imaginary engineer are real in the minds of far too many of our profession reluctant to giving up methods and procedures used successfully all of their professional lives to try something apparently intangible.

The personal, conversational computer, responding under the hands of an engineer, will do more to make the computer a real thing than will a library of XSECT or ALINE input sheets. Santa Fe found it virtually impossible to prevent the manual calculation of closures in an office fully advised as to the use of code sheets to be sent to our central processing unit. A conversational computer was installed in the building for use in programming and problem solution, and hand-calculated closures have been reduced to only those too simple to warrant coding. The computer for this office is now a fascinating, tangible thing.

The personalized conversational computer, using IBM's QUIKTRAN, deserves an important place in the plans of computer-minded engineers as it is a fast growing subset of the giant computer industry. It is presently tied telephonically into computers such as the IBM 7040/7044, and within a year it is likely to function with IBM's 360. Admittedly, it does have its limitations, but once the device is in house the engineer finds ways of circumventing these limitations to the point that programs that will fully tax a 360 may be developed and tested without undue difficulty. To demonstrate this point, Santa Fe is currently completing a hump yard simulation model that will be turned over to the 360 for implementation but not before it has been trimmed to acceptable size. The model was developed entirely on a conventional computer.

Also of very recent completion is a signal-spacing program which involved a train simulation for the many train configurations running over Santa Fe's system, supplementing the braking routine which makes an analysis of the current activities in the engine's cab and determines the proper braking procedure to be used, with all of its intricacies, to bring the train to a stop. Stopping distances, displayed with initial speeds, very nearly approximate actual field experiences. A future use is seen in the testing of different braking procedures. This entire program was developed and tested on a conversational computer, despite its so called limitations.

Don't overlook it. It is much more than a training tool.

But, getting on with the computer and the railroad engineer, not all of his problems have to do with large-scale enterprises with which many of the above computer uses are usually associated. To list but a few of the useful maintenance type of programs in Santa Fe's library:

ROLLIN—A conversational program which will completely analyze the "rolling in" of a long car, coupled to short cars, being drawn around a curve.

CLEAR —For system movement of high, wide loads.

CVST —For checking the consistency of curve records with respect to governing slow boards, super-elevation, and spiral lengths.

MILE —For the annual mileage statement to the ICC. To be implemented next year.

POND —Program supplementing Santa Fe's hydrology standard CES 5970 for the determination of watershed runoff and bridge openings.

TAYP —System side track records.

MTAYP —System main line records.

RAILFL—Under development. Will hold the record of rail failures and will point out patterns.

COOPR —Calculates car loading on bridge structures.

LISOC —Calculates line intersections with spirals or curves and their concentric right-of-way lines, a particularly troublesome calculation when either the spiral center line or its concentric right-of-way lines are involved.

This paper has discussed only a cross section of the programs available in the library of one railroad. Within the various departments of the many railroads represented by this group may be found programs that will satisfy most of the engineer's needs, and he may be assured that their sensible use will result in further development and availability of both programs and computers to make his lot one of ultimate productivity.

(The slides presented by Mr. Stane are reproduced on pages 314–327)

STATION 12000+00 TO 12203+29.5
M.P. 116.0 TO M.P. 119.85
TRANSITMAN RAS RODMAN ETL CHAINMAN RHK

LEVEL SECTION CODING SHEET -A-

LOCATION L.A. DATE 12-10-64
DIVISION L.A. PAGE 1 OF 3
DISTRICT 3rd CECL Nº 28-29839-14

MON	DAY	YR	LOCATION	STATE	NAME: INITIALS	NAME: LAST	EXAMPLE Nº 3A	SEQ. NO.
12	10	64	L.A.	CALIF	LM	JONES		1

"CODE": BLANK FOR "NO EQUATION INVOLVED"; 1 IF STATION IS THAT OF THE EAST SIDE OF AN EQUATION; 2 IF STATION IS THAT OF THE WEST SIDE OF AN EQUATION. (SHOW A SECTION AT BOTH SIDES OF ALL EQUATIONS)

STATION	GROUND ELEV.	ROADBED EXCAVATION: LEFT SLOPE ABOVE S/G	ROADBED EXCAVATION: R.B. WIDTH	ROADBED EXCAVATION: RIGHT SLOPE ABOVE S/G	ROADBED EMBANKMENT: LEFT SLOPE BELOW S/G	ROADBED EMBANKMENT: R.B. WIDTH	ROADBED EMBANKMENT: RIGHT SLOPE BELOW S/G	HIGH BENCH: SLOPE ABOVE BENCH	HIGH BENCH: BENCH WIDTH	HIGH BENCH: BENCH HEIGHT ABOVE S/G	LOW BENCH: SLOPE ABOVE BENCH	LOW BENCH: BENCH WIDTH	LOW BENCH: BENCH HEIGHT ABOVE S/G	HIGH BERM: SLOPE BELOW BERM	HIGH BERM: BERM WIDTH	HIGH BERM: BERM DEPTH BELOW S/G	LOW BERM: SLOPE BELOW BERM	LOW BERM: BERM WIDTH	LOW BERM: BERM DEPTH BELOW S/G	CODE	PERCENT ROCK	SEQ. NO.
12000000	20000	1	44	1	15	22	15															2
200	1986																					3
400	1972																					4
600	19555																					5
1000	1930																					6
2000	1980																					7
2300	2000																					8
3000	2000																					9
5200	2000													15	25	25						10
6000	19535																					11
925	1900	25	28	25							1	15	25								30	12
7500	2037																15	30	50			13
7800	2100																					14
12080000	2110																			1		15
12079000	2110																			2		16
12090000	2070																			1		17
12093000	2070																			2		18
12100000	2030																					19

LESEC input.

PROGRAM PEABODY
CODED BY RAS
CHECKED BY

"LESEC GRADE" DATA SHEET

DATE 1-25-65
PAGE 5 OF 6
CECL Nº 28-29630-22

* "KODE" – BLANK FOR "NO EQUATION INVOLVED". 1 FOR COURSE ENDING AT EQUATION ON TANGENT-GRADE. 2 FOR COURSE FOLLOWING EQUATION-ON-TANGENT. 3 FOR COURSE HAVING AN EQUATION BETWEEN B.V.C. AND CENTER OF V.C. 4 FOR COURSE HAVING AN EQUATION BETWEEN CENTER OF V.C. AND E.V.C. 5 FOR COURSE ENDING AT A V.C.P.I.—SHOW EAST AND WEST SIDES OF EQUATION IN EQUATION COLUMNS. 6 FOR USE WITH VARIATIONS OF GRADE ONLY.— SEE INSTRUCTIONS.

BEGINNING ELEVATION (1–9)	VERTICAL P.I. STATIONS (10–17)	SLOPE OF COURSE IN PERCENT. USE NEG. SIGN IF SLOPE IS NEGATIVE (18–23)	LENGTH OF VERTICAL CURVE IN FEET (24–29)	EQUATION: TO BE SHOWN ONLY IF WITHIN LIMITS OF VERTICAL CURVES. STATIONS EAST (30–38)	STATIONS WEST (39–47)	KODE		SEQ. NO. (75–80)
67ØØ	1ØØØØØ	-1258						83L
	1Ø66	-11465	12ØØ					84L
	11Ø56Ø	-1249	12ØØ					85L
	1198	-11288	1ØØØ					86L
	1264	-1227	1ØØØ					87L
	133	-11315	11ØØ					88L
	1396	-1284	11ØØ					89L
	14488Ø	-11136	9ØØ					9ØL
	1528	-1Ø63	11ØØ					91L
	16864Ø	-11439	14ØØ					92L
	17392Ø	-1Ø85	14ØØ					93L
	18976Ø	-1694	6ØØ					94L
	19768Ø	-1553						95L
	21Ø88Ø	-11152	6ØØ					96L
	21748Ø	-19Ø9	2ØØ					97L
	224Ø8Ø	-15Ø5	4ØØ					98L
	232	-1631	2ØØ					99L
	24784Ø	-1Ø94	6ØØ					1ØØL

LESEC grade.

PAGE 1

LEVEL SECTION QUANTITIES

AT OR NEAR PEADDY ,ARIZ

COMPILED 1,25,65. BY R.A. STANE

STATION	EMBANKMENT VOLUME CUBIC YDS.	EXCAVATION TOTAL VOLUME CUBIC YDS.	EXCAVATION ROCK VOLUME	SUB GRADE	GROUND ELEV	HEIGHT OF FILL	DEPTH OF CUT	
100000.0	0.0	0.0	0.0			0.0	0.0	PRORATED 0.0 SECTION
102640.0		16919.7	0.0	6693.19	6700.00		6.8	
105280.0		72215.0	0.0	6686.38	6700.00		13.6	
107060.2	0.0	98091.8	0.0			0.0	0.0	PRORATED 0.0 SECTION
110560.0	104447.1			6626.78	6600.00	26.8		
113200.0	225995.2			6618.38	6600.00	18.4		
115840.0	290534.6			6611.81	6600.00	11.8		
118480.0	319444.8			6605.24	6600.00	5.2		
119165.0	321295.4	98091.8	0.0			0.0	0.0	PRORATED 0.0 SECTION
121100.0		129258.4	0.0	6585.21	6600.00		14.8	
123471.5	321295.4	167455.2	0.0			0.0	0.0	PRORATED 0.0 SECTION
126400.0	368259.5			6518.27	6500.00	18.3		
129040.0	430095.0			6510.95	6500.00	10.9		
131680.0	456242.0			6504.96	6500.00	5.0		
133000.0	459799.0			6500.46	6500.00	0.5		
133840.4	509749.9				.	40.0		BERM 0.0 SECTION
134320.0	609439.6			6484.56	6422.00	62.6		
135640.0	1030411.6			6467.17	6400.00	67.2		
137758.8	1516819.7					40.0		BERM 0.0 SECTION
139600.0	1650853.3			6416.39	6400.00	16.4		
142240.0	1697998.6			6407.47	6400.00	7.5		
144573.7	1708081.0	167455.2	0.0			0.0	0.0	PRORATED 0.0 SECTION
144880.0		167705.6	0.0	6399.02	6400.00		1.0	
145503.6	1708081.0	168215.3	0.0			0.0	0.0	PRORATED 0.0 SECTION
152800.0	1765825.1			6311.48	6300.00	11.5		
158080.0	1827217.2			6306.68	6300.00	6.7		
163360.0	1855029.8			6303.35	6300.00	3.4		
166447.5	1859828.6	168215.3	0.0			0.0	0.0	PRORATED 0.0 SECTION
168640.0		172699.2	0.0	6297.62	6300.00		2.4	
170069.8	1859828.6	175623.3	0.0			0.0	0.0	PRORATED 0.0 SECTION
173920.0	1873368.6			6226.41	6220.00	6.4		
175240.0	1908404.2			6222.89	6200.00	22.9		
179200.0	2069444.7			6219.40	6200.00	19.4		
181840.0	2253089.0			6217.08	6180.00	37.1		
182276.4	2301606.8					40.0		BERM 0.0 SECTION
183160.0	2424616.0			6215.92	6170.00	45.9		
183643.2	2491886.1					40.0		BERM 0.0 SECTION

LESEC display.

PROGRAM BLINE
CODED BY L. M. JONES
CHECKED BY K.L.S

"BLINE" DATA SHEET

EXAMPLE N°2

DATE 2-19-65
PAGE 1 OF 1
CECL Nº 28-?2339-13

SHOT NO. (4)	AZIMUTH D (7)	AZIMUTH M (9)	AZIMUTH S (11)	LENGTH FEET (18)	SIDE SHOT (19)	COORDINATES AT POINT OF BEGINNING NORTH (30)	EAST (41)	LAST (42)	FILE NO. (47)	SEQ. NO. (74–78)	(80)
Ø						1ØØØØØ	1ØØØØØ		13	1	
1	29Ø	2Ø		118Ø¦						2	
2	22	1Ø	42	42Ø¦93	1					3	
3	28Ø	1Ø	1Ø	245 ¦						4	
4	193	17	44	1Ø89¦87						5	
5	21Ø	2Ø	2Ø	157Ø¦21						6	
6	323	56	13	2415¦61						7	
7	282	58	22	8698¦47						8	
8	218	21	46	13657¦67						9	
9	Ø	Ø	Ø	Ø¦	1					1Ø	
1Ø	13Ø	1Ø	Ø	8						11	
11	Ø	Ø	Ø	Ø¦	1					12	
12	59	Ø1	23	2521¦32						13	
13	54	49	47	2921¦34	1			1		14	

Note: See Example 2A for sketch of this problem.

BLINE input.

BLINE

SHOT NO	WORK COURSE OR SIDE SHOT AZIMUTH D M S	WORK COURSE OR SIDE SHOT LENGTH FEET	SIDE SHOT	COORDINATES NORTH	COORDINATES EAST	ALINE COURSE NUMBER	ALINE COURSE AZIMUTH D M S	ALINE COURSE LENGTH FEET	FILE NUMBER	LAST
0				100000.00	100000.00				13	
1	290 20 0	1180.00	0	100410.02	98893.53					0
1002	22 10 42	420.93	1	100799.80	99052.43					0
						1	310 9 57	1239.99		0
3	280 10 10	2450.00	0	100842.59	96482.02					0
1004	193 17 44	1089.87	1	99781.94	96231.38					0
						2	250 9 36	2999.06		0
5	210 20 20	1570.21	0	99487.42	95688.89					0
1006	323 56 13	2415.61	1	101440.12	94266.88					0
						3	310 10 0	2570.76		0
1007	282 58 22	8698.47	1	101440.12	87212.43					0
						4	270 0 0	7054.45		0
8	218 21 46	13657.67	0	88778.48	87212.41					0
1009	0 0 0	0.00	1	88778.48	87212.41					0
						5	180 0 0	12661.64		0
10	130 10 0	8000.00	0	83618.38	93325.78					0
1011	0 0 0	0.00	1	83618.38	93325.78					0
						6	130 10 0	8000.00		0
12	59 1 23	2521.32	0	84916.09	95487.50					0
1013	54 49 47	2921.34	1	86598.80	97875.53					1
						7	56 46 20	5439.03		1

END OF JOB

BLINE output.

PROGRAM ALINE
CODED BY
CHECKED BY

"ALINE" DATA SHEET -A-

DATE 9·15·64
PAGE 1 OF 2
CECL Nº 28-29639-9

MO	DAY	YR	LOCATION	STATE	NAME (INITIALS / LAST)	E.S. AT POINT OF BEGINNING STAP	COORDINATES AT POINT OF BEGINNING NORTH TNP	EAST TEP	SEQ NO.
9	15	64	KINGMAN	ARIZ	RH BEEDER	1ØØØØØ	1ØØØØØ	1ØØØØØ	1

COURSE NO	SUB	AZIMUTH OF COURSE D M S	LENGTH OF COURSE DZ	CV	DEGREE OF CURVE D M S	SPL LENGTH SPL	POC	DEF	SEQ NO
1		31Ø1Ø	124Ø						2
2		25Ø1Ø	3ØØØ						3
3		31Ø1Ø	257Ø76		23ØØØ			1	4
4		27Ø	7Ø5445		2ØØØØ			1	5
5	1	18Ø	1ØØØØ		1ØØØØ	57Ø		1	6
5	2	1ØØ1Ø1Ø	6ØØ						7
5	3	175	12ØØ						8
5	4	16Ø	22ØØ						9
5	5	1123Ø15	25ØØ						1Ø
5	6	2Ø2	6ØØ						11
5	9	13Ø1Ø							12
6	1	13Ø1Ø	2ØØØ		1ØØØØ	57Ø	1	1	13
6	2	8Ø	8ØØ						14
6	3	85	2ØØØ						15
6	9	7Ø1Ø							16
7		7Ø1Ø	3ØØØ		3ØØØØ	4ØØ	1	1	17
999									18

ALINE input.

PROGRAM ______
CODED BY ET
CHECKED BY ______

"GRADE" DATA SHEET -A-

DATE ______
PAGE 1 OF ______
CECL Nº 28-29639-11

MON	DAY	YR	LOCATION	STATE	NAME: INITIALS	NAME: LAST	E. S. AT POINT OF BEGINNING	ELEV. AT POINT OF BEGINNING	B/R (INSERT 1 IF BASE OF RAIL PROFILE)	SEQ NO
9	14	64	ELSINORE	CAL	FET	LUCEY	1199ØØØ	2Ø1ØØØ	1	1P

"CODE" – BLANK FOR "NO EQUATION INVOLVED". 1 FOR COURSE ENDING AT EQUATION ON TANGENT-GRADE. 2 FOR COURSE FOLLOWING EQUATION-ON-TANGENT. 3 FOR COURSE HAVING AN EQUATION BETWEEN B.V.C. AND CENTER OF V.C. 4 FOR COURSE HAVING AN EQUATION BETWEEN CENTER OF V.C. AND E.V.C. 5 FOR COURSE ENDING AT A V.C. P.I. — SHOW EAST AND WEST SIDES OF EQUATION IN EQUATION COLUMNS.

"STAS" – BLANK FOR 100 FT. STATIONS. 1 FOR 50 FT STATIONS. EFFECTIVE FROM LAST E.V.C. THROUGH V.C.

BEGINNING ELEVATION	VERTICAL P.I. STATIONS	SLOPE OF COURSE IN PERCENT. USE NEG SIGN IF SLOPE IS NEGATIVE	LENGTH OF VERTICAL CURVE IN FEET	EQUATION STATIONS EAST	EQUATION STATIONS WEST	STAS	CODE	SEQ NO.
2Ø1ØØØ	1199ØØØ1Ø	-11Ø						2P
	12Ø153Ø1Ø	-Ø128	8ØØ					3P
	12Ø43ØØ1	-Ø172	11ØØ					4P
	12Ø48501	-Ø172					1	5P
	12Ø48251	-Ø172					2	6P
	12Ø73ØØ1	-Ø116	14ØØ					7P
	121ØØØØ1	124	8ØØ	12Ø97ØØ	12Ø97212	1	3	8P
	12125ØØ1	176	16ØØ					9P
	12143ØØ1	1358	1ØØØ	1214444	121445Ø		4	1ØP
	12195801	-Ø1222	15ØØ					11P
	12222201	Ø1Ø	6ØØ	122222Ø	12222ØØ	1	5	12P
	1223ØØØ1	1148	4ØØ					13P
	-1							14P

GRADE input.

BASE OF RAIL ELEVATIONS PAGE 1

AT CR NEAR ELSINORE,CALF

COMPILED 9,14,64. BY E.T.LUCEY

BEGINNING ENGINEERS STATION 1199000.0

BEGINNING ELEVATION 2010.00

STATION	SUB GRADE ELEVATIONS TO TENTHS	SUB GRADE ELEVATIONS TO HUNDREDTHS	BASE OF RAIL ELEVATIONS	P.I. ELEVATIONS	PERCENT OF GRADE	LENGTH OF VERTICAL CVE	RATE OF CHANGE
1199000.0				2010.00	-1.000		
1199050.0	0.0	0.00	2009.50				
1199100.0	0.0	0.00	2009.00				
1199150.0	0.0	0.00	2008.50				
1199200.0	0.0	0.00	2008.00				
1199250.0	0.0	0.00	2007.50				
1199300.0	0.0	0.00	2007.00				
1199350.0	0.0	0.00	2006.50				
1199400.0	0.0	0.00	2006.00				
1199450.0	0.0	0.00	2005.50				
1199500.0	0.0	0.00	2005.00				
1199550.0	0.0	0.00	2004.50				
1199600.0	0.0	0.00	2004.00				
1199650.0	0.0	0.00	2003.50				
1199700.0	0.0	0.00	2003.00				
1199750.0	0.0	0.00	2002.50				
1199800.0	0.0	0.00	2002.00				
1199850.0	0.0	0.00	2001.50				
1199900.0	0.0	0.00	2001.00				
1199950.0	0.0	0.00	2000.50				
1200000.0	0.0	0.00	2000.00				
1200050.0	0.0	0.00	1999.50				
1200100.0	0.0	0.00	1999.00				
1200150.0	0.0	0.00	1998.50				
1200200.0	0.0	0.00	1998.00				
1200250.0	0.0	0.00	1997.50				
1200300.0	0.0	0.00	1997.00				
1200350.0	0.0	0.00	1996.50				
1200400.0	0.0	0.00	1996.00				
1200450.0	0.0	0.00	1995.50				
1200500.0	0.0	0.00	1995.00				
1200550.0	0.0	0.00	1994.50				

GRADE display.

X-SECTION CODING SHEET -A-

STATION 1200000 TO 1201700 LOCATION L B DATE 8-27-64
M.P. 22.7 TO M.P. ____ DIVISION L A PAGE 1 OF 10
TRANSITMAN ETL RODMAN ____ CHAINMAN ____ DISTRICT HARBOR CECL Nº 28-29639-16

MON	DAY	YR	LOCATION	STATE	NAME: INITIALS	NAME: LAST		73	SEQ. NO.
8	27	64	LONG BEACH	CALIF	ET	LUCEY		1	1G

A — IF FILL, LEAVE BLANK. IF CUT, INSERT 1.
B — IF SECTION OR ELEMENT OF COMPOUND SECTION COMPLETE, LEAVE BLANK. IF SECTION CONTINUED ON NEXT LINE, INSERT 1. IF O.O SECTION, INSERT 2. IF REPEAT SECTION, INSERT 3. IF WEST SIDE OF EQUATION, INSERT 4.
C — FOR MIXED SECTIONS. IF THE SECTION IS COMPRISED OF BOTH CUT AND FILL, INSERT 1.

STATION	LEFT SLOPE	LEFT WIDTH	RIGHT WIDTH	RIGHT SLOPE	H.I.	GRADE RD. LT. CROWN (33)	RODS / DISTANCES (37)	(41)	(45)	(49)	(53)	(57)	(61)	(65)	(69)	A	B	C	SEQ. NO.
12000000	15	11	11	15													2		2G
																			3G
1200000						0	600	650	530	620	700	00							4G
						11	1010	700	00	500	1160	110							5G
1201200																	3		6G
																			7G
1201400						0	300	260	240	260	160	200	100	160	110		1		8G
						11	560	460	400	300	150	120	100	00	20				9G
						60	40	20	20	00	00								10G
						30	50	60	80	90	11								11G
1201600																	3		12G
																			13G
12016000	10	22	22	10												1	2		14G
																			15G
1201700																	2		16G
																			17G
1201700						0	0	51	100	00						1			18G
						220	220	000	320	220									19G

XSECT input.

```
                                  CROSS SECTICN QUANTITIES COMPILED AS OF   8/27/64
                               AT OR NEAR      LONG BEACH,CALIF BY E.T.LUCEY

  ENGR.      EXCAV.      EMBKT. S/GRADE LEFT     CROWN     RIGHT         SECTIONS          ROOS                          PAGE  1
 STATION      C.Y.        C.Y.    ELEV. SLOPE  LEFT RIGHT  SLOPE                          DISTANCES

1200000.0                  0.0     0.0 1.500  11.0  11.0 1.500

                                                                               0.0 SECTION

1201000.0              128213.0  1990.0 1.500  11.0  11.0 1.500

                                          0.0 -60.0 -65.0 -53.0 -62.0 -70.0   0.0
                                         11.0 101.0  70.0   0.0  50.0 116.0  11.0

1201200.0              179498.1  1988.0 1.500  11.0  11.0 1.500

                                                                             REPEAT SECTION

1201400.0              207316.7  1986.0 1.500  11.0  11.0 1.500

                                          0.0 -30.0 -26.0 -24.0 -26.0 -16.0 -20.0 -10.0 -16.0 -11.0  -6.0  -4.0  -2.0
                                         11.0  56.0  46.0  40.0  30.0  15.0  12.0  10.0   0.0   2.0   3.0   5.0   6.0

                                         -2.0   0.0   0.0
                                          8.0   9.0  11.0

1201600.0              211668.5  1984.0 1.500  11.0  11.0 1.500

                                                                             REPEAT SECTION

1201600.0       0.0              1984.0 1.000  22.0  22.0 1.000

                                                                               0.0 SECTION

1201700.0              212756.5  1983.0 1.500  11.0  11.0 1.500

                                                                               0.0 SECTION

1201700.0     453.7              1983.0 1.000  22.0  22.0 1.000

                                          0.0   0.0   5.0  10.0   0.0
                                         22.0  22.0   0.0  32.0  22.0

1201900.0    2268.5              1981.0 1.000  22.0  22.0 1.000
```

XSECT display.

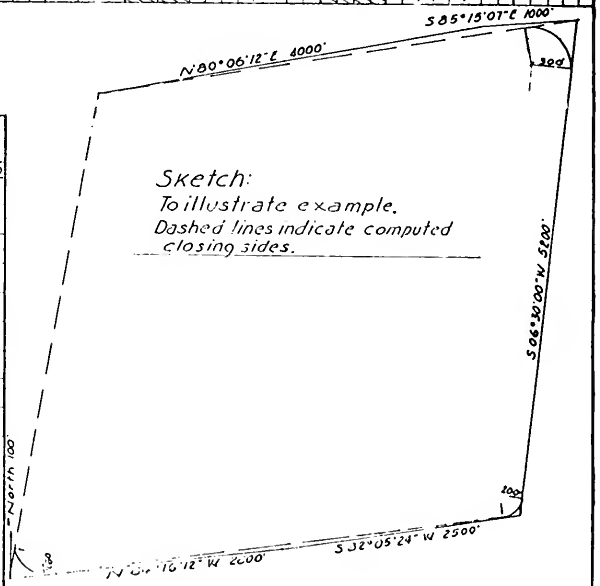
PROGRAM CLOSR
CODED BY L. M. JONES
CHECKED BY K. L. S.

"CLOSR" DATA SHEET -A- EXAMPLE Nº 6-F

DATE 12-1Ø-6?
PAGE 6 OF 6
CECL Nº 28-29639-20

MONTH	DAY	YEAR	IDENTIFICATION	COORDINATES AT POINT OF BEGINNING NORTH	EAST	SEQ. NO.
12	1Ø	64	HYPO FORCED CLOSURE OF SERIES BY ADJUSTMENT			37

COURSE NO.	HOLD	N	S	DEG	MIN	SEC	E	W	LENGTH OF COURSE	RADIUS OF CURVE AT THE END OF THE COURSE	LAST	FORCE	SERIES	FIXED	FINAL	SEQ. NO.
1		/		8Ø	Ø6	12	/		4ØØØ				/			38
2			/	85	15	Ø7	/		1ØØØ	3ØØ	/	/		/		39
3			/	6	3Ø			/	52ØØ	2ØØ	/	/		/		4Ø
4			/	82	Ø5	24		/	25ØØ							41
5		/		84	16	12		/	28ØØ	28Ø	/	/		/		42
6		/		Ø	Ø	Ø			1ØØ		/	/	2		/	43



CLOSR input.

CLOSR TRAVERSE PROGRAM

MONTH DAY YEAR	IDENTIFICATION
11 1 1964	HYPOTHETICAL CLOSED TRAVERSE

COMPUTED BEARINGS ACCURATE TO 0.05 SECOND

S U R V E Y

COURSE NUMBER	HOLD COURSE	BEARING	DEG	MIN	SEC		DISTANCE	RADIUS	LAST COURSE	FORCED CLOSURE	SERIES OF CLOSURES	FIXED COURSE OF SERIES	COORDINATES OF INITIAL POINT NORTH	EAST
													134766.210	124785.620
1	0	N	82	14	7.150	E	5172.560	0.000	0	0	0	0	135465.040	129910.750
2	1	S	1	2	14.000	W	5291.620	0.000	0	0	0	0	130174.290	129814.970
3	0	S	82	12	16.000	W	5171.250	0.000	0	0	0	0	129472.870	124691.520
4	0	N	1	4	23.000	E	5290.280	0.000	1	0	0	0	134762.220	124790.590

THE ERRORS TO BE ADJUSTED BELOW ARE 3.9900 FEET IN THE NORTHING AND -4.9700 FEET IN THE EASTING./

ADJUSTMENT
....

COURSE NUMBER	BEARING	DEG	MIN	SEC		DISTANCE	RADIUS	CURVE LENGTH	SEMI-TANGENT	DELTA DEG MIN SEC	COORDINATES NORTH	EAST
1	N	82	13	37.376	E	5170.177					135455.460	129908.290
2	S	1	2	14.000	W	5291.620					130174.710	129812.510
3	S	82	12	45.810	W	5173.630					129473.710	124686.600
4	N	1	4	18.843	E	5293.433					134766.210	124785.620

THE AREA IS 620.92961 ACRES, 27047694.000 SQUARE FEET.

CLOSR display.

PROJECT Kingman Reloc.
LOCATION Ariz.

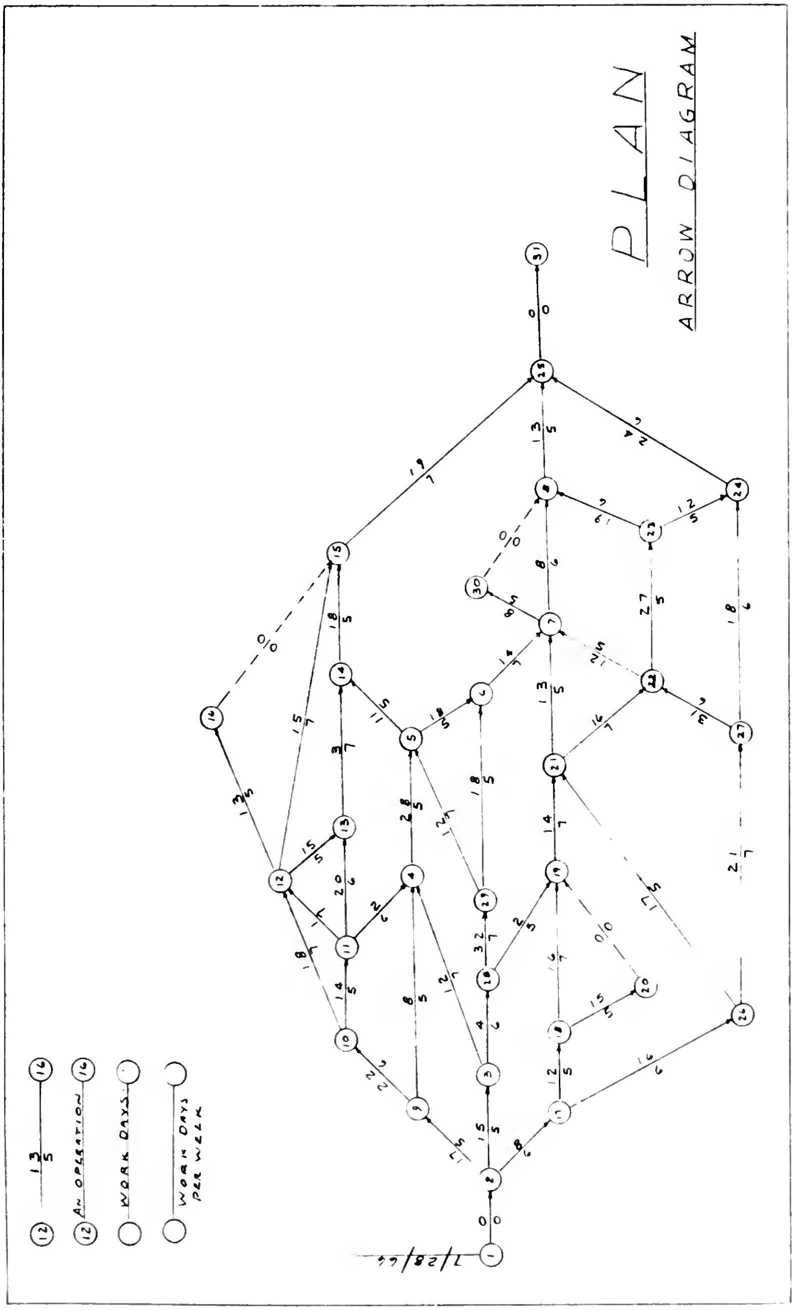
PLAN SHEET A

DATE 6/17/66
PAGE 1 OF 3
CECL 28-29639-39-A

BEGINNING DATE OF PROJECT (MONTH / DAY / YEAR)	DATE OF THIS REPORT (MONTH / DAY / YEAR)	PROJECT IDENTIFICATION	SEQ. NO.
7 / 28 / 66	6 / 17 / 66	KINGMAN RELOCATION PROPOSAL	1Ø

TOTAL NO. OF ACTIVITIES	JOB ACTIVITY IDENTIFICATION NUMBERS: BEG. NO.	END NO.	DAYS ESTIM. FOR JOB ACTIV.	BLANK FOR 5 DAY WEEK. 1 FOR 6 DAY WEEK. 2 FOR 7 DAY WEEK. 9 FOR LAST ENTRY.	JOB ACTIVITY DESCRIPTION	SEQ. NO.
51	1	2	Ø		BEGIN	2Ø
	2	3	15		SURVEYS FILE .256	3Ø
	3	4	12	2	SOILS INVEST. FILE 7	4Ø
	4	5	28		DESIGNS PER SCHEDULE 8 AND CONSTRUCT	5Ø
	5	6	18		CONSTRUCT OFF RAMP 1	6Ø
	6	7	14	2	INSTALL PROTECTION LAMP 1	7Ø
	7	8	8	1	CONSTRUCT RAMP 2	8Ø
	8	25	13		PROTECT RAMP 2	9Ø
	2	9	17		TRAFFIC STUDY FREEWAY	1ØØ
	9	4	8		OBTAIN APPROVAL	11Ø
	13	14	32	2	TRANSITION PLANNING	12Ø
	9	1Ø	22	1	INSTALL DETOUR	13Ø
	1Ø	11	14		GRADE EAST ENTRANCE	14Ø
	1Ø	12	18	2	INSTALL TEMP. WATER SYSTEM	15Ø

PLAN input.



PLAN diagram.

Report of Committee 27—Maintenance of Way Work Equipment

°**R. M. Johnson**, *Chairman*
°**C. E. Turner**, *Vice Chairman*
°**F. H. Smith**, *Secretary*
°**Emil Eskengren**
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°L. W. Cantwell
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M. M. Stansbury
E. A. Stewart
J. P. Titus
S. E. Tracy (E)
J. W. Winger
W. W. Wynne
F. E. Yockey
G. L. Zipperian
Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 27.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
The committee reviewed the material in Chapter 27 of the Manual, and it was the consensus that no changes are necessary at this time.

1 (a). Revision of Handbook of Instructions for Care and Operation of Maintenance of Way Equipment.
Brief status report, presented as information .... page 330

2. Improvements to be made to existing work equipment.
This committee has been jointly involved in correcting the Handbook in conjunction with manufacturers. No specific report is presented on this subject at this time.

3. Switch heaters and other devices or machines for removing snow from switches.
Progress report, presented as information .... page 330

4. Selection, installation and maintenance of road-rail attachments.
The committee has assembled extensive information for a report to be submitted in the future.

6. Track lining equipment.
   The committee is assembling information for a report to be submitted in the future.
7. Rail laying equipment.
   A survey of equipment used by various railroads and other additional information is needed to prepare a report, which will be done in the future.

THE COMMITTEE ON MAINTENANCE OF WAY WORK EQUIPMENT,
R. M. JOHNSON, *Chairman.*

AREA Bulletin 610, December 1967

Report on Assignment 1 (a)

Revision of Handbook of Instructions for Care and Operation of Maintenance of Way Equipment

C. R. TURNER (chairman, subcommittee), J. V. ADAMS, R. W. BAILEY, C. A. BEEMER, R. E. BERGGREN, L. W. CANTWELL, J. W. CUMMINGS, A. C. DANKS, JAMES DESKO, C. F. HUNT, F. S. HUNTER, N. W. HUTCHISON, R. K. JOHNSON, E. W. KNIGHT, W. E. KROPP, JACK LARGENT, C. F. LEWIS, H. E. MCQUEEN, A. W. MUNT, C. H. OLDS, J. P. PORCHER, H. C. POTTSMITH, W. W. WYNNE.

Your committee submits the following status report as information.

In our previous report on revision of Handbook, as published in Vol. 68, 1967, page 254, it was stated that we had been given permission by the Board of Direction to use manufacturers' names both in the Handbook and index. To further increase the utility of the Handbook, it will be made a loose-leaf type.

The committee has reviewed all material in the Handbook and is now compiling the reports. The Handbook revision will be completed by the next Annual Meeting.

Report on Assignment 3

Switch Heaters ad Other Devices or Machines For Removing Snow From Switches

J. W. RISK (chairman, subcommittee), J. V. ADAMS, R. M. BALDOCK, C. A. BEEMER, D. E. COWELL, J. W. CUMMINGS, V. L. EMAL, E. H. FISHER, C. F. HUNT, W. LENCO, M. M. STANSBURY, H. A. THYNG, J. P. TITUS.

This report is submitted as information, with the recommendation that the subject be continued.

Previous reports on snow-melting and other devices developed to effect the removal of snow from switches may be found in the Proceedings, Vol. 54, 1953, pages 686 to 697, Vol. 67, Bulletin 596, December 1965, pages 254 to 265 and Vol. 68, Bulletin 603, December 1966, pages 255 to 262.

Five distinct makes of switch heaters, including one using compressed air, were reported on in the 1965 report, together with a number of portable machines designed specifically to remove snow from switches.

LONG, FIXED, GAS-FIRED HEATERS

Type A Gas-Fired Heater

The 1966 report provided additional information on the heaters reported on in 1965 and made reference to a type of gas-fired heater not covered in the previous report. Some 200 of this latter type, designated herein as Type A Gas-Fired Heater, were used by United States and Canadian railways during the winter of 1966–67 with encouraging results. Two of these were thoroughly tested under extreme winter conditions by the Canadian National Railways at Montreal. One was installed at the northwest end of the dual hump yard, just below the master retarders, in an extremely exposed, wind-swept area. The heaters in this section of the yard have to be lit frequently and for considerable periods of time not only for the duration of the snowfalls, but also to cope with drifts created by blowing snow. Since other heaters in this location are lit manually, the test installation (although provided with electrical ignition) also had to be turned on, which merely involved flipping a switch in its control box.

The other test heater, also with manual control, was installed on the Montreal Subdivision's eastbound main line switch at Ballantyne, where a deep cut provides a canyon-like corridor with extreme wind action, accentuated by the high speed of the trains (up to 90 mph) over the switch. Snow is swept up and is dumped almost continuously into the turnout, especially in the switch point area.

Installations at both of these locations were completed before the first snowfall and provided a complete winter season's operation.

Type A Heater—Test Results on CN

Installation:

The units are compact and standardized, and can be easily handled. Two men can cope with their deployment, and the same two men with a foreman can install an entire unit in two to three hours. If installed in quantities, two experienced men can easily perform this task within two hours (provided propane gas installation is already on site). A further advantage is that neither track time nor a slow order is required.

Performance:

The winter of 1966 and 1967 was an extremely severe one, requiring perhaps the most intensive utilization of switch heaters since the hump yard opened in 1958, with an average of 300 hours for each unit. Extremely low temperatures down to —25 F coupled with high winds traditionally have posed problems for switch heaters, as the extremely high rate of loss of heat cannot be compensated for by the heaters, thus reducing their effectiveness under such conditions.

In general, the performance of the heater designated herein as Type A has been fairly satisfactory. Manufacturers claims have largely been substantiated even under the most severe conditions. When the heaters worked they did what they were designed to do, i.e., they kept the switch points free of snow and created no ice. They were immune to blow-outs by even the highest winds or air currents created by high-speed trains. They seem to have generated and transferred enough heat to the rail to maintain the melting and evaporating process. At milder temperatures, overheating of the rail was effectively prevented by the "rail temperature control unit", which reduced the supply of gas reaching the burners to 25 percent if the

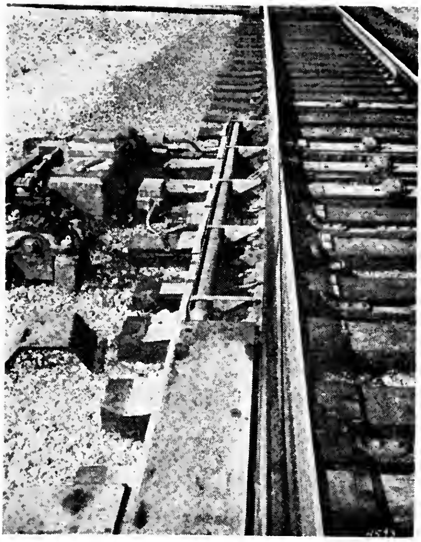


Fig. 1

rail temperature at the base of the rail reached 150 F. Fuel gas supply was automatically re-established when the base of rail temperature dropped to 140 F. This feature is extremely significant, not only in terms of keeping the rail temperature at an even and narrow range, but can also be meaningful in controlling excessive gas consumption.

The foregoing analysis is not intended to indicate that the heaters were entirely trouble-free. Minor problems were encountered in keeping the heaters operational, and were corrected.

Fuel Consumption:

No reliable fuel consumption figures were established at the test sites, as these heaters drew gas from a large supply tank, jointly serving other gas-fired heaters.

Type B Gas-Fired Heater

A third type of gas-fired heater, designated herein as Type B and illustrated in Fig. 1, was developed for the Union Pacific Railroad and was reported to have operated successfully on that line. It was installed for test purposes on a crossover in Montreal.

A study of the unit will reveal its relative complexity when compared with the other gas-fired heaters. Heavy piping, substantial burners and relatively large inspirator devices (huge boxes on both sides of the switch) all represent a lot of hardware.

Type B Heater—Test Results

Installation:

The entire unit is separate from the rail structure. The heater is supported by 12 pedestals (six on each side), which have to be dug into place. The installation of piping and inspirator boxes represents a considerable amount of labor. The dimensions of the inspirator box are such that it cannot be installed between two tracks in double-track territory, thus the crossing of another track with piping is necessitated. Indications are that under normal circumstances, and with some experienced men, installation of this type of heater would consume approximately 100 man-hours.

Performance:

Some difficulties were experienced with its operation after the heater was placed in service on February 9. The burners had to be constantly adjusted. The absence of a rail temperature-control device coupled with apparent maladjustment of the burners resulted in overheating of the rails, thus requiring constant attention. Consequently, all the burners were dismantled, taken back to the shop and, with the help of the manufacturer's representative, were readjusted.

After the reinstallation, the heater performed satisfactorily for the rest of the winter, during which only three small snowfalls occurred. This prevented reaching any conclusions about its reliability throughout an entire winter season.

Fuel Consumption:

With the limited working period, and the problems associated with maladjustment of burners, no full consumption figures were obtained. The different characteristics of the heater and the extremely low gas pressure required would tend to indicate that fuel consumption figures would be considerably below that of other gas-fired heaters presently in use.

FIXED, INFRARED RADIATION HEATERS, GAS-FIRED

The 1966 report covered fixed, infrared radiation gas-fired heaters of a type extensively used on European railroads. Our attention has been directed to a second type, featuring overhead installation, designed to eliminate track maintenance interference and assure a better concentrated pattern of the infrared ray to the switch area. It is provided with a completely automatic moisture- and temperature-control unit. A special extended-time feature which can be preset for any desired period up to four hours will allow the burners to continue operating after moisture sensors have indicated that the area has dried out. This assures the melting of any remaining snow or ice in the switch area.

The manufacturer claims that this heater has an estimated 60 percent longer life than track-type heaters because they are substantially free from the vibrations of train traffic, also that high maintenance costs due to vibrations are substantially reduced. It is further stated that fuel consumption is lower than for many other types due to the combined use of gas-fired infrared heaters and the fully automatic control which allows the burners to operate only when needed. The electric control is furnished for use with either a-c or d-c current. The control has a great sensitivity range and extended time selector feature to meet all conditions. The electrical power draw is very low and within the limits available at remote switch locations where power is quite limited.

It is reported that 35 heaters of this type, illustrated in Figs. 2 and 3, have been installed on Santa Fe lines.

SUMMARY

Perhaps the most important development in switch heaters to date is tests being undertaken by the National Research Council of Canada in collaboration with the Canadian Pacific and Canadian National Railways.

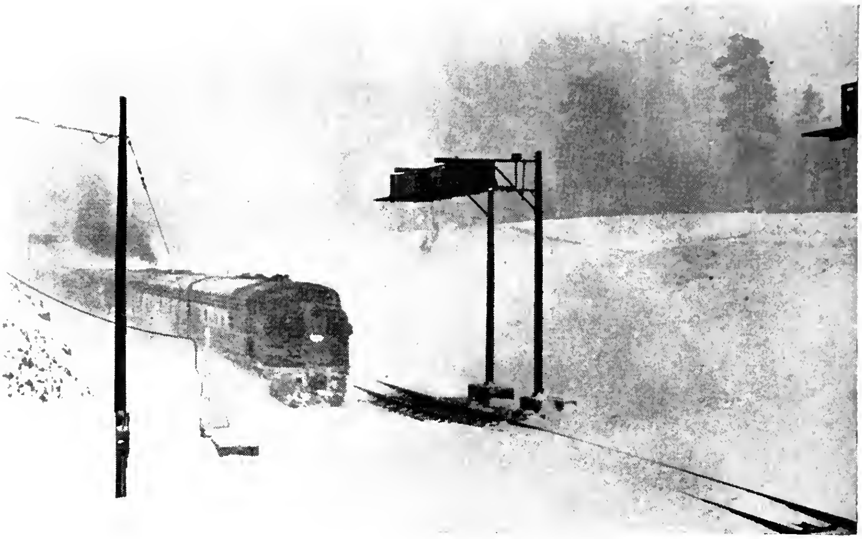


Fig. 2

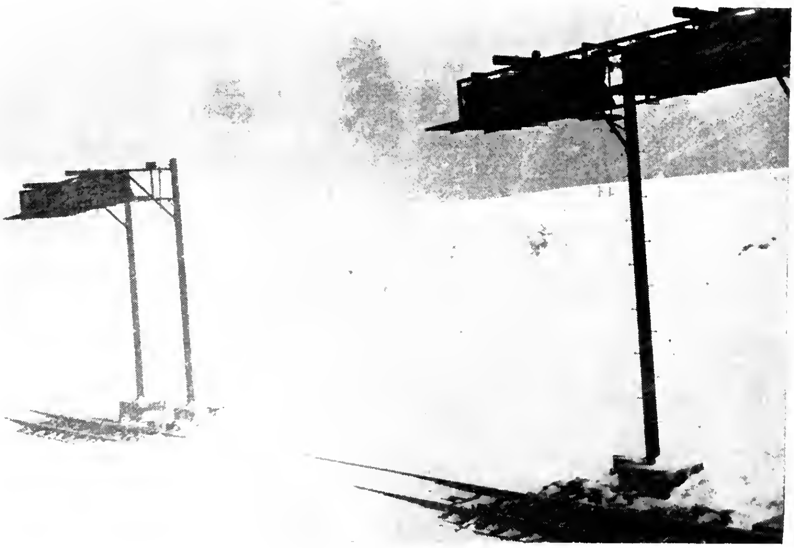


Fig. 3

Two different makes of gas-fired heater and one type of oil-fired hot-air blower have been tested. Initially, these heaters were tested in the field at Uplands, where the National Research Council has a railway laboratory. One gas-fired and one oil-fired heater have been tested in the cold room at Ottawa, Ont. To ensure proper testing, a pair of power-operated 22-ft switch points were installed in the cold room, complete with ties, ballast, etc. The temperature in the cold room can be lowered to —70 F and snow can be produced at rates up to 1 inch per hour with winds up to 45 mph.

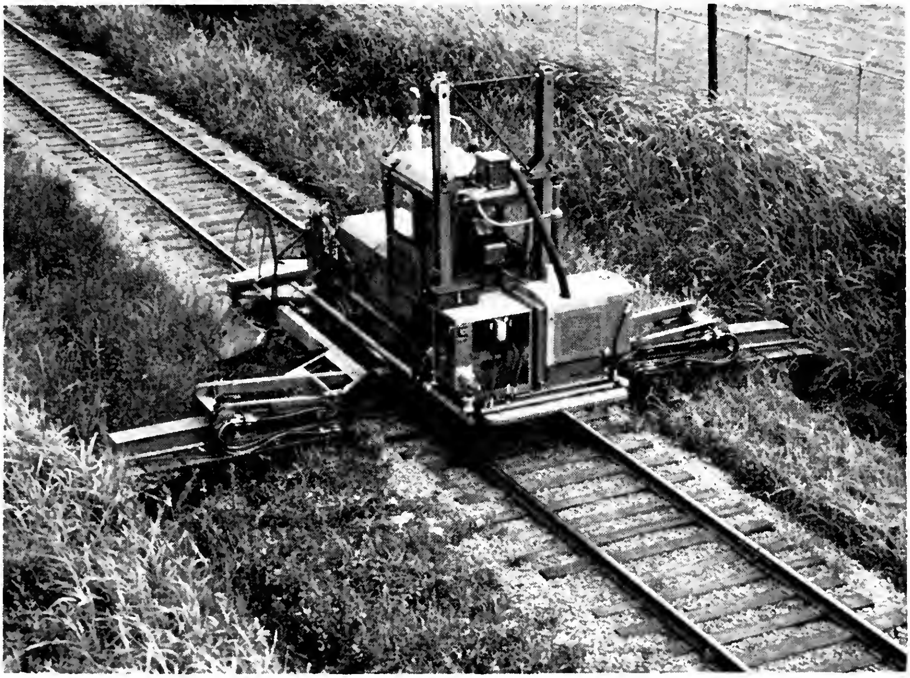
Initial tests have indicated that, unless some form of enclosure is provided at the switch, the loss of heat to the atmosphere is such that all heaters tested failed to perform efficiently under less than extreme conditions. Testing has indicated that, to ensure proper operation of a power switch, heat from any type of heater must be directed into the open switch points and onto the switch slide plates. The only means of doing this effectively is by means of moving air and enclosing the switch point area. Testing has indicated that for a 22-ft switch point a set of shields 17 ft long must be provided at each point, with the center of the switch closed in with plywood and all crib ends blocked. Air from a fan, heated by oil, propane, or natural gas, is ducted under the shield and by means of nozzles at each tie crib is allowed to pass up through the open switch point.

This method was used in testing the two types of switches down to —25 F with snowfall of 1 in per hour and winds up to 45 mph, with entirely satisfactory results, whereas previous tests resulted in failure at approximately +15 F under the same conditions of snow and wind.

A ½-hp motor drawing about 7 to 9 amp at 115 v is used with the oil-fired heater with closed-in switch points for the operation of the fan. The propane-type heater was operated with a ¼-hp fan motor and required 4 amp at 115 v. A measure of success has been obtained using a propane heater with a ⅛-hp fan motor which requires 2.2 amp at 115 v. Further testing is to be undertaken both in the laboratory and field to evaluate results and determine if a ¼-hp fan motor on the oil-fired type heaters will provide sufficient air to efficiently keep snow out of a switch. The volume of air required for a 22-ft switch heated to rail temperatures ranging from +50 F to a maximum of +100 F appears to be in the range of 800 cfm.

Control of heaters by means of snow detectors is also being studied, but at this time little progress has been made and further tests are being undertaken.

We understand that the National Research Council will make the results of these tests available to the railroad industry in due course, and further information will be presented by your committee in 1968.



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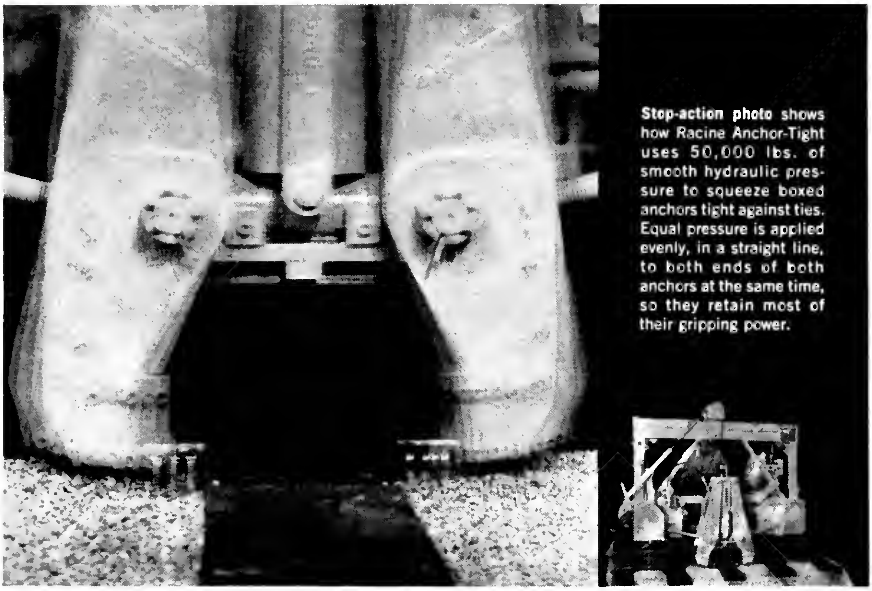

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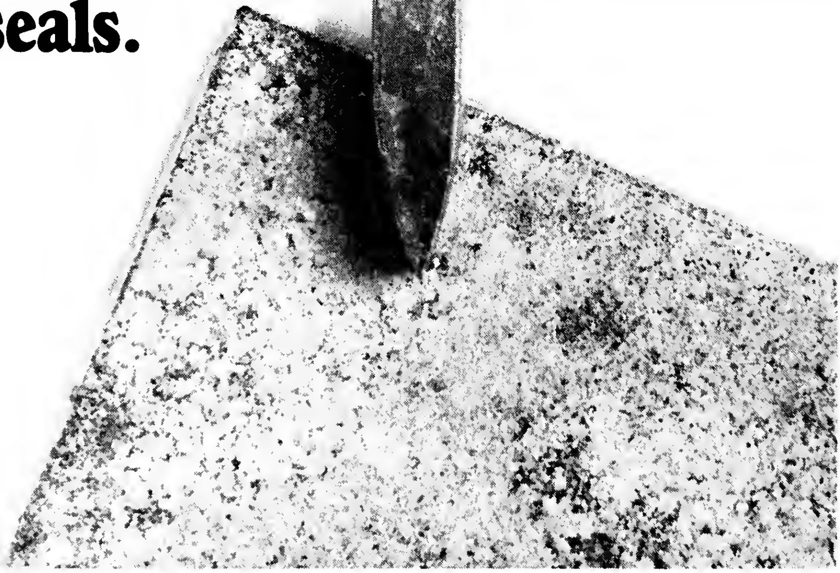

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Proceedings Vol. 69*

MANUAL RECOMMENDATIONS

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MANUAL RECOMMENDATIONS

All the Manual recommendations submitted by committees for adoption and publication in the 1968 Supplement to the AREA Manual of Recommended Practice are printed below, on pages 337 to 384, incl. These recommendations will be formally submitted for concurrent review and approval to the AREA Board of Direction Committee on Manual and the Vice President, Operations and Maintenance Department, Association of American Railroads. Comments or objections by Members regarding any of these recommendations should be submitted to the Executive Secretary not later than FEBRUARY 15, 1968.

Manual Recommendations

Committee 1—Roadway and Ballast

Report on Assignment 6

Roadway: Formation and Protection

G. F. Nigh (chairman, subcommittee), H. E. Bartlett. D. L. Bloem, S. F. Burmeister, I. P. Cook, H. K. Eggleston, J. F. Faycosh, M. B. Hansen, E. M. Hardin, H. O. Ireland, E. C. Jordan, A. E. Lewis, W. G. Murphy, J. E. Newby, S. R. Pettit, W. J. Sponseller, C. E. Webb.

Your committee submits the following editorial changes in Chapter 1 of the Manual.

Pages 1–1–23 to 1–1–36, incl.

ROADWAY PROTECTION

On page 1–1–26, in the third line from the bottom of the page, insert the word "slag" between the words "gravel" and "crushed stone." In the second line from the bottom of the page, insert the word "suitable" between the words "other" and "granular."

Manual Recommendations

Committee 3—Ties and Wood Preservation

Report on Assignment 3

Wood Preservatives

W. W. Barger (chairman, subcommittee), W. F. Arksey, A. B. Baker, R. G. Brohaugh, C. A. Burdell, D. L. Davies, R. F. Dreitzler, K. C. Edscorn, W. R. Jacobson, J. J. McManus, L. M. Nichols, T. H. Patrick, O. W. Smith, H. K. Wyant, R. G. Zietlow.

(a) Keep Up to Date Current Specifications for Preservatives
(b) New Preservatives

Under Assignment 3 (a) your committee has made changes in the specifications for preservatives in Chapter 17 of the Manual in order to bring them up to date with the same specifications of other national organizations. Some of the changes are editorial, others are minor that help to more nearly describe the preservative.

These preservatives are:

Creosote, page 17–2–1.
Creosote–Coal Tar Solutions, page 17–2–2.
Creosote–Petroleum Solution, page 17–2–3.
Petroleum for Blending with Creosote, page 17–2–3.
Chromated Zinc Chloride (CZC), page 17–2–4.
Fluor–Chrome–Arsenate–Phenol Type A (FCAP Type A), page 17–2–5.
Acid Copper Chromate (ACC), page 17–2–7.
Ammoniacal Copper Arsenite (ACA), page 17–2–10.
Chromated Copper Arsenate (CCA), page 17–2–11.
Petroleum for Pentachlorophenol and Copper Naphthenate, page 17–2–12.
Fluor–Chrome–Arsenate–Phenol Type B (FCAP Type B), page 17–2–13.
Copperized Chromated Zinc Arsenate (CuCZA), page 17–2–14.

The revised versions of the aforementioned preservatives are printed below.

Your committee is also recommending the deletion of the following salt preservatives due to their decline in use:

Copperized Chromated Zinc Chloride (CuCZC), page 17–2–8.
Chromated Zinc Arsenate (CZA), page 17–2–9.

Under Assignment 3 (b) your committee is offering for your approval a new preservative, Solubilized Copper-8-Quinolinolate. This preservative has a limited use, but we feel that it should be included in our list of salt preservatives. This preservative is approved specifically for the treatment of wood which might come in contact with foodstuffs. The specification for this preservative is also printed below.

CREOSOTE

1. The creosote shall be a distillate derived entirely from tar produced by the carbonization of bituminous coal.

2. It shall contain not more than 1.5 percent water.

3. It shall contain not more than 0.5 percent matter insoluble in benzol (See Note 1.)

4. The specific gravity of the creosote at 38 deg C compared with water at 15.5 deg C shall be not less than 1.050.

5. The distillate, percent by weight on a water-free basis shall be within the following limits (See Note 1):

	Not Less Than	*Not More Than*
Up to 210 deg C		2.0
Up to 235 deg C		12.0
Up to 270 deg C	20.0	40.0
Up to 315 deg C	45.0	65.0
Up to 355 deg C	65.0	82.0

6. The specific gravity of fraction between 235 deg C and 315 deg C shall be not less than 1.027 and fraction between 315 deg C and 355 deg C not less than 1.095 at 38 deg C compared with water at 15.5 deg C.

7. The creosote shall yield not more than 2 percent of coke residue.

8. Tests to determine the foregoing requirements shall be made in accordance with AWPA Standard A1.

Note 1—Due to treating operations, samples of used creosote may show increases in water content, matter insoluble in benzol, and in coke residue and decreases in percentage of distillate up to 235 deg C. If it can be shown that the original creosote was of the specified quality, and the used creosote conforms to the standard requirements with the following exceptions:

Water content, max, percent	*3.0*
Benzol insoluble matter, max, percent	*1.5*
Coke residue, max, percent	*3.0*
Distillate up to 235 deg C, min, percent	*2.0*

it shall be considered as conforming.

CREOSOTE–PETROLEUM SOLUTION

Creosote–petroleum solution shall consist solely of a mixture of specifid proportions of coal tar creosote which meets AREA specifications for creosote and of petroleum which meets AREA specifications for petroleum for blending with creosote. No creosote–petroleum solution shall contain less than 50 percent by volume of such creosote or more than 50 percent by volume of such petroleum.*

* Owing to the lack of suitable methods of analysis, it is not possible to determine the relative amounts of either component once these materials have been blended. The purchaser may, therefore, wish to consider obtaining the materials separately and having them blended under his supervision.

PETROLEUM FOR BLENDING WITH CREOSOTE

Petroleum for blending with creosote shall conform to the following requirements:

Specific gravity at 60 deg F not less than 0.96 (not greater than 15.9 deg API) ASTM D 287.

Petroleum of lower specific gravity may be used provided experience or test shows that it may be blended with creosote without the formation of excessive sludge.

Water and Sediment BS&W, not more than 1 percent, ASTM D 96.

Flash point not less than 175 deg F as determined by the Pensky–Martens Closed Tester, ASTM D 93.

The viscosity shall be not less than 40 sec and preferably not more than 60 sec, although oils of higher viscosity may be used, providing that penetration requirements are met. The purchaser may specify the viscosity best suited to his requirements, allowing the supplier a tolerance of plus or minus 10 percent of the value specified. Viscosity shall be in terms of Saybolt Universal seconds at 210 deg F, ASTM D 88.

Tests to determine the foregoing requirements shall be made in accordance with the ASTM method as indicated. The ASTM standards referred to herein may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. 19103.

CHROMATED ZINC CHLORIDE (CZC)

Chromated zinc chloride shall have the following composition:

	Percent
Zinc chloride ($ZnCl_2$)	81.5
Sodium dichromate ($Na_2Cr_2O_7.2H_2O$)	18.5

subject to following tolerances:

The composition of the solid preservative or the preservative present in a freshly prepared treating solution may vary within the following limits:

	Min Percent
Water-soluble zinc calculated as $ZnCl_2$	77.5
Hexavalent chromium calculated as $Na_2Cr_2O_7.2H_2O$	17.5

Hexavalent chromium may include chromium trioxide sufficient to produce in a 3 percent solution of chromated zinc chloride a pH no lower than 3.0 as determined by a pH meter or pH paper of confirmed accuracy.

Samples of chromated zinc chloride treating solution taken from working tanks or treating cylinder may show a change in composition as a result of treating operations. Such changes shall not serve to cause rejection of the preservative, if they do not raise the ratio of zinc chloride to sodium dichromate dihydrate to more than 8 to 1, and if it can be shown that the original fresh preservative was of the specified composition.

Tests to determine the foregoing requirements shall be made in accordance with AWPA Standard A2.

FLUOR-CHROME-ARSENATE-PHENOL TYPE A (FCAP TYPE A)

Fluor-chrome-arsenate-phenol type A shall have the following composition:

	Percent
Fluoride calculated as sodium fluoride (NaF)	25
Arsenate calculated as disodium hydrogen arsenate (Na_2HAsO_4)	25
Chromate calculated as sodium chromate (Na_2CrO_4)	37½
Dinitrophenol *[$(NO_2)_2C_6H_3 \cdot OH$]	12½

* An equal amount of sodium pentachlorophenate may be used in place of dinitrophenol.

Composition of the solid preservative or of the preservative present in a treating solution may vary within the following limits:

	Min Percent	*Max Percent*
Fluoride calculated as NaF	22	28
Arsenate calculated as Na_2HAsO_4	22	28
Chromate calculated as Na_2CrO_4	34	41
Dinitrophenol [$(NO_2)_2C_6H_3 \cdot OH$]	10	15

The solid preservative shall contain at least 95 percent of the active ingredients listed above.

The pH of the treating solution shall be not less than 7.2 nor more than 7.8.

Tests to determine the foregoing requirements shall be made in accordance with AWPA Standard A2.

ACID COPPER CHROMATE (ACC)

Acid copper chromate shall be composed of the following ingredients in the proportions given:

	Percent
Copper sulfate ($CuSO_4 \cdot 5H_2O$)	50.0
Sodium dichromate ($Na_2Cr_2O_7 \cdot 2H_2O$)*	48.3
Chromic acid (CrO_3)**	1.7

* Potassium dichromate may be used in place of sodium dichromate.

** Acetic acid may be used in place of chromic acid. The amount of acetic acid used shall be such as to yield a treating solution with pH of not less than 2.0 or more than 4.2.

The proportions of the ingredients of the dry salt or chemicals in treating solution may vary within the following limits:

	Max Percent	*Min Percent*
Copper calculated as $CuSO_4 \cdot 5H_2O$	55	45
Hexavalent chromium calculated as $Na_2Cr_2O_7 \cdot 2H_2O$	55	45

The pH of the treating solution shall be not less than 2.0 nor more than 4.2.

The preservative shall contain at least 95 percent of the active ingredients listed above.

Tests to determine the foregoing requirements shall be made in accordance with AWPA Standard A2.

CHROMATED COPPER ARSENATE TYPE A (CCA TYPE A)

Chromated copper arsenate Type A in the solid state shall be composed of the following ingredients in the proportions given:

	Percent
Potassium dichromate ($K_2Cr_2O_7$)*	56
Copper sulfate ($CuSO_4 \cdot 5H_2O$)**	33
Arsenic pentoxide ($As_2O_5 \cdot 2H_2O$)***	11

* An equivalent amount of sodium dichromate and/or chromic acid (CrO_3) may be used in place of potassium dichromate.

** An equivalent amount of basic copper carbonate ($CuCO_3$-$Cu(OH)_2$) may be used in place of copper sulfate.

*** An equivalent amount of arsenic acid may be used in place of arsenic pentoxide.

The proportions of the ingredients in the solid preservative, or in treating solution may vary within the following limits:

	Min Percent	*Max Percent*
Hexavalent chromium calculated as $K_2Cr_2O_7$	50	60
Copper calculated as $CuSO_4 \cdot 5H_2O$	30	37
Pentavalent arsenic calculated as $As_2O_5 \cdot 2H_2O$	10	13

The preservative shall contain at least 95 percent of the active ingredients listed above.

Tests to determine the foregoing requirements shall be made in accordance with AWPA Standard A2.

SOLUBILIZED COPPER-8-QUINOLINOLATE

Solubilized copper-8-quinolinolate shall have the following composition:

	Percent
Copper-8-quinoliniolate, wt min	10.0
Nickel-2-ethyhexoate, wt min	10.0
Inert ingredients (hydrocarbon solvents) wt min	80.0
	100.0

Physical Properties:

Copper as metal, wt min	1.80
Nickel as metal, wt min	1.80
pH	5.5–6.5
Specific gravity at 77 deg F	0.935–0.975

Solubility—Completely soluble in aliphatic and aromatic solvents which comply with the standards of the AREA.

Solubilized copper-8-quinolinolate should be free of amines, phosphoric acid, or naphthenic acid and its derivatives.

Tests to determine the foregoing requirements shall be made in accordance with AWPA Standards.

Note—This preservative is recommended only for above-ground use. It is approved specifically for the treatment of wood which might come in contact with foodstuffs. A retention of 0.3 lb per cu ft is recommended.

AMMONIACAL COPPER ARSENITE (ACA)

Ammoniacal copper arsenite shall be composed of the following ingredients in the proportions given:

	Percent
Copper hydroxide [$Cu(OH)_2$]	57.7
Arsenic trioxide (As_2O_3)	40.7
Acetic Acid (CH_3COOH)	1.6

The above shall be dissolved in a solution of ammonia (NH_3) in water. The weight of ammonia contained in the treating solution shall be from 1.5 to 2.0 times the weight of the copper hydroxide.

The proportions of the chemicals in the treating solution may vary within the following limits:

	Max Percent	*Min Percent*
Copper calculated as $Cu(OH)_2$	59.7	55.7
Trivalent arsenic calculated as As_2O_3	42.7	38.7

The preservative shall contain at least 95 percent of the active ingredients listed above.

Tests to determine the foregoing requirements shall be made in accordance with AWPA Standard A2.

PETROLEUM SOLVENT FOR PENTACHLOROPHENOL AND COPPER NAPHTHENATE

Petroleum as a solvent for pentachlorophenol and copper naphthenate shall conform to the following requirements:

Specific gravity at 60 deg F not less than 0.85 (not greater than 35 API) ASTM D 287.

Water and Sediment BS&W, not more than 0.5 percent, ASTM D 96.

Flash point not less than 150 deg F determined by Pensky–Martens closed tester. ASTM D 93.

Distillation range shall be as follows as determined by ASTM Method D 158:

50-percent point not lower than 500 deg F (260 deg C)

90-percent point not lower than 600 deg F (315.5 deg C)

The viscosity shall be not more than 70 Saybolt Universal seconds at 100 deg F although oils of higher viscosity may be used providing penetration requirements are met. The purchaser may specify the viscosity best suited to his requirements, allowing the supplier a tolerance of plus or minus 10 percent of the value specified. ASTM D 88.

The petroleum shall dissolve at least 10 percent by weight of pentachlorophenol at 75 deg F. AWPA Method A5.

FLUOR-CHROME-ARSENATE-PHENOL TYPE B (FCAP TYPE B)

Fluor-chrome-arsenate-phenol Type B shall be composed of the following:

	Percent
Sodium fluoride (NaF)	34
Sodium arsenate (Na_2HAsO_4)	25
Sodium dichromate *($Na_2Cr_2O_7 \cdot 2H_2O$)	34
Dinitrophenol [$(NO_2)_2C_6H_3 \cdot OH$]	7

* Potassium dichromate may be substituted for sodium dichromate.

subject to following tolerances:

The composition of the solid preservative or the preservative in the treating solution may vary in the following limits:

	Min Percent	*Max Percent*
Fluoride calculated as NaF	31	37
Pentavalent arsenic calculated as Na_2HAsO_4	22	28
Hexavalent chromium calculated as $Na_2Cr_2O_7 \cdot 2H_2O$	31	37
Dinitrophenol [$(NO_2)_2C_6H_3 \cdot OH$]	5	9

The solid preservative shall contain at least 95 percent of the active ingredients listed above.

The pH of the treating solution shall be not less than 5.5 or more than 6.5.

Tests to determine the foregoing requirements shall be made in accordance with AWPA Standard A2.

COPPERIZED CHROMATED ZINC ARSENATE (CuCZA)

Copperized chromated zinc arsenate in the solid state shall be composed of the following ingredients in the proportions given:

	Percent
Arsenic acid (H_3AsO_4)	20
Sodium Arsenate (Na_2HAsO_4)	21
Sodium dichromate ($Na_2Cr_2O_7 \cdot 2H_2O$)	16
Zinc sulfate ($ZnSO_4 \cdot 7H_2O$)	21.5
Copper sulfate ($CuSO_4 \cdot 5H_2O$)	21.5

The proportions of the ingredients in the solid preservative or in the treating solution may vary within the following limits:

	Min Percent	*Max Percent*
Pentavalent arsenic calculated as total H_3AsO_4 plus Na_2HAsO_4 in a ratio of 20 to 21	37	42.5
Hexavalent chromium calculated as $Na_2Cr_2O_7 \cdot 2H_2O$	14	18
Zinc calculated as $ZnSO_4 \cdot 7H_2O$	20.5	22.5
Copper calculated as $CuSO_4 \cdot 5H_2O$	20.5	22.5

The solid preservative, or salts in solution, shall be considered to meet the requirements with respect to arsenic compounds if the total arsenic content calculated as As_2O_5 lies between 26.4 and 31.1 percent and the pH of solution containing 25 grams per liter of the solid preservative measured at 25 deg C lies between 2.90 and 3.50.

The solid preservative shall contain at least 95 percent of the active ingredients listed above.

Tests to determine the foregoing requirements shall be made in accordance with AWPA Standard A2.

CREOSOTE–COAL TAR SOLUTION FOR THE PRESERVATION OF PILES AND TIMBERS FOR USE IN COASTAL WATERS

1. The material shall be a pure coal tar product derived entirely from tar produced by the carbonization of bituminous coal.
2. Composition: The material shall be a solution of coal tar in coal tar creosote.
3. It shall conform to the following detailed requirements:

	Not Less Than	*Not More Than*
4. Water—percent by volume		3.0
5. Material insoluble in benzol* percent	1.0	3.0
6. Coke residue* percent	4.0	7.0
7. Specific gravity at 38 deg C compared to water at 15.5 deg C	1.090	
8. Distillation*: The distillate percent on a water-free basis shall be within the following limits:		
Up to 210 deg C		5.0
Up to 235 deg C	5.0	15.0
Up to 270 deg C	20.0	35.0
Up to 315 deg C	35.0	50.0
Up to 355 deg C	55.0	70.0
9. Specific gravity of fractions at 38 deg compared to water at 15.5 deg C		
Fraction 235 deg C—315 deg C	1.030	
Fraction 315 deg C—355 deg C	1.105	
10. Specific gravity of distillation residue above 355 deg C at 38 deg C compared to water at 15.5 deg C	1.185	
11. Tests to determine the foregoing requirements shall be made in accordance with AWPA Standard A1.		

** Due to treating operations, samples of used solution may show an increase in material insoluble in benzol and in coke residue and decreases in percentage of distillate up to 235 deg C. A used solution shall be considered as conforming if it can be shown that the original solution was of specified quality and the used solution conforms to the standard requirement within the following limits:*

Benzol insoluble, maximum, percent	*4.0*
Coke Residue, maximum, percent	*8.0*
Distillate up to 235 deg C, min, percent	*2.0*

COAL TAR CREOSOTE FOR THE PRESERVATION OF PILES AND TIMBERS FOR USE IN COASTAL WATERS

1. The creosote shall be a distillate derived entirely from tar produced by the carbonization of bituminous coal.
2. It shall contain not more than 1.5 percent water, by volume.
3. It shall contain not more than 0.5 percent matter insoluble in benzol.*
4. The specific gravity of the creosote at 38 deg C compared with water at 15.5 deg C shall not be less than 1.080.
5. The distillate on a water-free basis shall be within the following limits:

	Not Less Than	*Not More Than*
Up to 210 deg C—percent		2.0
Up to 235 deg C—percent		12.0*
Up to 270 deg C—percent	20.0	40.0
Up to 315 deg C—percent	45.0	65.0
Up to 355 deg C—percent	65.0	75.0

6. The specific gravity of fractions at 38 deg C compared with water at 15.5 deg C:
   Fraction 235 deg C-315 deg C, not less than 1.030
   Fraction 315 deg C-355 deg C, not less than 1.105
7. The specific gravity of the distillation residue above 355 deg C shall be not less than 1.160 at 38 deg C compared to water at 15.5 deg C.
8. The creosote shall yield not more than 2.0 percent coke residue.*
9. Tests to determine the foregoing requirements shall be made in accordance with AWPA Standard A1.

** Due to treating operations, samples of used creosote may show increases in water, matter insoluble in benzol and in coke residue.*

A used creosote shall be considered as conforming if it can be shown that the original creosote was of specified quality, and the used creosote conforms to the standard requirements within the following limits:

Water content, max, percent	*3.0*
Benzol insoluble matter, max, percent	*1.5*
Coke residue, max, percent	*3.0*

Report on Assignment 4

Preservative Treatment of Forest Products

L. C. Collister (chairman, subcommittee), W. F. Arksey, G. W. Brenton, C. A. Burdell, R. E. Case, D. L. Davies, R. F. Dreitzler, K. C. Edscorn, J. J. McManus, C. S. Morton, T. H. Patrick, R. B. Smith, F. M. Whitmore, R. G. Zeitlow.

Your committee submits for adoption the following recommendations with respect to Chapter 17 of the Manual:

Pages 17–4–1 to 17–4–18.1, incl.

SPECIFICATIONS FOR TREATMENT

On page 17-4-5, delete Sec. C—Results of Treatment, and Sec. D—Preservatives, substituting therefor the following:

C. RESULTS OF TREATMENT

1. Retention of Preservative

The net retention in any charge shall be not less than 90 percent of the quality of preservative that may be specified; but the average retention by the material treated under any contract or order and the average retention of any 5 consecutive charges shall be at least 100 percent of the quantity required, unless specified, and treated to refusal. The amount of preservative retained shall be calculated from reading of working-tank gages, or scales, or from weights before and after treatment of loaded trams on suitable track scales, with the necessary corrections for changes in moisture content, or by the assay method. Recommended minimum retentions for various materials for various uses are contained in Table 1.

The retention of oil-borne and water-borne preservatives shall be expressed in pounds of dry preservative per cubic foot. The volume and specific gravity correction tables of the AREA shall be used in calculating retention.

The volume of oil-borne preservatives shall be calculated on the basis of 100 deg F. Calculations of volume or weight shall be made by the use of temperature or specific gravity factors contained in the volume and specific gravity correction tables of the AREA.

The amount of preservative retained shall be in accordance with Table 1, unless modified by the purchaser.

The penetration of preservative shall be as specified in Table 1.

2. Plugging Penetration Test Holes

All holes made for determining penetration of preservative shall be filled with tight-fitting treated plugs.

D. PRESERVATIVES

The preservative used shall be whichever of the following specifications of the AREA is stipulated:

CREOSOTE-TYPE PRESERVATIVES

(1) Creosote

(2) Creosote–Coal Tar Solutions*

(3) Creosote–Petroleum Solutions*

WATER-BORNE PRESERVATIVES

(1) Ammoniacal Copper Arsenite (ACA)

(2) Acid Copper Chromate (ACC)

(3) Chromated Copper Arsenate (CCA)

(4) Fluor–Chrome–Arsenate Phenol Type A (Tanalith) (FCAP Type A)

(5) Fluor–Chrome–Arsenate–Phenol Type B (Osmose Salts) (FCAP Type B)

OIL-BORNE PRESERVATIVES

(1) Pentachlorophenol

(2) Copper Naphthenate

(3) Solubilized Copper-8-Quinolinolate

* Retentions for creosote-coal tar and creosote-petroleum solutions are based on a 50 percent creosote solution.

COMMENT

Water-borne preservatives are recommended for preservative treatment of all classes of wood except marine piling; however, as a general rule, they have not been found entirely satisfactory for cross ties because they do not help to protect the wood mechanically, are subject to leaching over long periods and, thus, will decay and affect circuit conductivity. The quantity of water-borne preservatives that should be used for various purposes are included under specific requirements for preservative treatment by pressure process.

Delete Tables of Specific Requirements for Preservative Treatment by Pressure Processes, on pages 17-4-8, 17-4-9, 17-4-10, 17-4-15, 17-4-16, 17-4-16.1, and 17-4-18.1, substituting therefor the accompanying revised tables.

G. SPECIFIC REQUIREMENTS FOR PRESERVATIVE TREATMENT
BY PRESSURE PROCESSES

Table 1-Specific Requirements for Preservative Treatment
By Pressure Processes

(Lumber, Timber and Bridge Ties) 17-4-8

	Southern Pine Ponderosa Pine		Jack Pine Red Pine Sugar Pine	Lodgepole Pine Northern White Pine Western White Pine
CONDITIONING	Air seasoning, accelerated air seasoning, kiln drying, steaming, or heating in the preservative or a combination.		Air seasoning, accelerated air seasoning, kiln drying, steaming, or heating in the preservative or a combination.	
Steaming				
Temp.-deg F-max	245		240	
Duration-hr-max	17		6	
Vacuum				
Inches at sea level-min	22		22	
Heating in preservative				
Temp.-deg F-max	220		220	
Incising	Not required		Required when thickness is greater than 3 in	
TREATMENT				
Creosote-type preservatives	Empty or full-cell		Empty or full-cell	
Water-borne preservatives	Full-cell		Full-cell	
Oil-borne preservatives	Empty or full-cell		Empty or full-cell	
Pressure-psi-max	200		150	
Final steaming				
Temp.-deg F-max	245		240	
Duration-hr-max	3		3	
RESULTS OF TREATMENT				
Retention-lb per cu ft-min				
Creosote-type preservatives	General Use	Coastal Waters*	General Use	Coastal Waters*
Creosote	8	Ref. min 20	8	Refusal
Creosote-coal tar	8	Ref. min 20	8	Refusal
Creosote-petroleum	8	Not recommended	8	Not recommended
Water-borne preservatives**	Above Ground	Ground Contact	Above Ground	Ground Contact
ACA	0.30	0.50	0.30	0.50
ACC	0.50	1.00	0.50	1.00
CCA	0.35	0.55	0.35	0.55
CZC	0.75	1.00	0.75	1.00
CuCZA	0.50	1.00	0.50	1.00
FCAP Type A	0.35	0.50	0.35	0.50
FCAP Type B	0.35	0.55	0.35	0.55
Oil-borne preservatives				
Pentachlorophenol***	0.3	0.4	0.3	0.4
Solubilized Copper 8 Quinolinolate****	0.20	NR	0.20	NR
Copper Naphthenate (Copper Metal)	0.05	0.1	0.05	0.1
Penetration in inches or percent of sapwood-min	3.0" or 85%		Under 3" thick-0.375" or 90% 3" and thicker and all marine structures-0.50" and 90%	
Determination of penetration.	A borer core shall be taken from 20 pieces in each charge. If 90% of the cores meet the penetration requirements the charge shall be accepted.		A borer core shall be taken from 20 pieces in each charge. If 80% of the cores meet the penetration requirements, the charge shall be accepted.	

*Subject to marine borer attack.
**Not recommended where leaching is a major consideration.
***Treating solution must contain approximately 5% Penta.; 0.4 lb per cu ft equals 8 lb of 5% Penta. solution.
****This preservative has the approval of the Food and Drug Administration for the preservative treatment of lumber used in areas where food is harvested, stored and transported.

Table 1 (Cont'd)-Specific Requirements for Preservative Treatment
By Pressure Processes

(Lumber, Timbers and Bridge Ties, Cont'd) 17-4-9

	Pacific Coast Douglas Fir, Intermountain Douglas Fir, Western Hemlock, Western Larch		Oaks	
CONDITIONING	Air-seasoning, accelerated air-seasoning, kiln drying, steaming, or heating in the preservative or a combination.		Air-seasoning, accelerated air-seasoning, kiln drying, or heating in the preservative or a combination.	
Steaming				
Temp.-deg F-max	240*		Not permitted	
Duration-hr-max	6			
Vacuum				
Inches at sea level-min	22			
Heating in preservative				
Temp.-deg F-max	200		220	
Incising	Required when thickness over 3"		Not required	
TREATMENT				
Creosote-type preservatives	Empty or full-cell		Empty or full-cell	
Water-borne preservatives	Full-cell		Full-cell	
Oil-borne preservatives	Empty or full-cell		Empty or full-cell	
Pressure-psi-max	150		200	
Final steaming				
Temp.-deg F-max	240		240	
Duration-hr-max	3		3	
RESULTS OF TREATMENT				
Retention-lb per cu ft-min				
Creosote-type preservatives	General Use**	Coastal Waters***	General Use	Coastal Waters***
Creosote	8	12 or refusal	6	Refusal min 10
Creosote-coal tar	8	12 or refusal	6	Refusal min 10
Creosote-petroleum	8	Not recommended	6 Applies to red oak only. White Oak to be treated to refusal.	Not recommended
Oil-borne preservatives	Above Ground	Ground Contact	Above Ground	Ground Contact
Pentachlorophenol*****	0.30	0.4	0.30	0.4
Solubilized Copper 8 Quinolinolate******	0.20	NR	0.20	NR
Copper naphthenate (Copper metal)	0.05	0.1	0.05	0.1
Water-borne preservatives****	Above Ground	Ground Contact	Above Ground	Ground Contact
ACA	0.30	0.50	0.30	0.50
ACC	0.50	1.00	0.50	1.00
CCA	0.35	0.55	0.35	0.55
CZC	0.75	1.00	0.75	1.00
CuCZA	0.50	1.00	0.50	1.00
FCAP Type A	0.35	0.50	0.35	0.50
FCAP Type B	0.35	0.55	0.35	0.55
Penetration in inches or percent of sapwood-min	Under 3" thick 0.375" and 90%. 3" and thicker and all marine structures 0.50" and 90%. Intermountain Douglas fir 90% of sapwood.		White oak-95% of sapwood Red oak-65% of annual rings; charges of recalcitrant wood with less penetration may be accepted if wood is conditioned properly before treatment and treatment is continued to refusal.	
Determination of penetration	A borer core shall be taken from 20 pieces in each charge. If 80% of the cores meet the penetration requirements the charge shall be accepted.		A borer core shall be taken from 20 pieces in each charge. If the average penetration of the 20 cores meets the penetration requirements the charge shall be accepted.	

*See Fundamentals, Part 1, this Chapter.

**8 lb is general average retention. Thin material should have more than 8 lb. Heavy timbers generally reach refusal with less.

***Subject to marine borer attack.

****Not recommended where leaching is a major consideration.

*****Treating solution must contain approximately 5% Penta.; 0.4 lb per cu ft equals 8 lb of 5% Penta. Solution.

******This preservative has the approval of the Food and Drug Administration for the preservative treatment of lumber used in areas where food is harvested, stored and transported.

Table 1 (Cont'd)-Specific Requirements for Preservative Treatment
By Pressure Processes

(Lumber, Timbers and Bridge Ties, Cont'd) 17-4-10

	Gums	
CONDITIONING	Air-seasoning, accelerated air-seasoning, kiln drying, steaming, or heating in the preservative or a combination.	
Steaming		
Temp.-deg F-max	240	
Duration-hr-max	6	
Vacuum		
Inches at sea level-min	22	
Heating in preservative		
Temp.-deg F-max	220	
Incising	Not required	
TREATMENT		
Creosote-type preservatives	Empty or full-cell	
Water-borne preservatives	Full-cell	
Oil-borne preservatives	Empty or full-cell	
Pressure-psi-max	200	
Final steaming		
Temp.-deg F-max	240	
Duration-hr-max	3	
RESULTS OF TREATMENT		
Retention-lb per cu ft-min		
Creosote-type preservatives	General Use	Costal Waters*
Creosote	9	Refusal-min 12
Creosote-coal tar	9	Refusal-min 12
Creosote-petroleum	9	Not recommended
Water-borne preservatives**	Above Ground	Ground Contact
ACA	0.30	0.50
ACC	0.50	1.00
CCA	0.35	0.55
CZC	0.75	1.00
CuCZA	0.50	1.00
FCAP Type A	0.35	0.50
FCAP Type B	0.35	0.55
Oil-borne preservatives		
Pentachlorophenol	0.3	0.4
Solubilized Copper 8 Quinolinolate***	.20	NR
Copper Naphthenate (Copper metal)	0.05	0.1
Penetration in inches or percent of sapwood-min	1.5" or 85%	
Determination of penetration	A borer core shall be taken from 20 pieces in each charge. If 80% of the cores meet the penetration requirements the charge shall be accepted.	

*Subject to marine borer attack.
**Not recommended where leaching is a major consideration.
***This preservative has the approval of the Food and Drug Administration for the preservative treatment of lumber used in areas where food is harvested, stored and transported.

Table 1 (Cont'd)-Specific Requirements for Preservative Treatment
By Pressure Processes

(Posts) 17-4-15

	Southern Pine Ponderosa Pine		Jack Pine	
CONDITIONING	Air-seasoning or steaming, or heating in the preservative or a combination.		Air-seasoning or steaming (for ice-coated or frozen posts only) or heating in the preservative or a combination.*	
Steaming				
Temp.--deg F--min	...		...	
max	245		240	
Duration-hr-min	...		...	
max	10		3	
Vacuum				
Inches at sea level--min	22		22	
Duration--hr--min	1		½	
max	3		2	
Heating in preservative				
Temp.--deg F--max	220		220	
Duration--hr--max	...		...	
TREATMENT				
Expansion bath				
Temp.--deg F--max	220		220	
Pressure--lb--max	200		150	
Final Steaming				
Temp.--deg F--max	245		245	
Duration--hr--max	3		3	
RESULTS OF TREATMENT				
Retention--lb per cu ft--min				
Creosote and creosote solution				
Creosote	6		6	
Creosote-coal tar	6		6	
Creosote-petroleum	7		7	
Oil-borne preservatives				
Pentachlorophenol	0.30		0.30	
Water-borne preservatives	Above Ground	Ground Contact	Above Ground	Ground Contact
ACA	0.30	0.50	0.30	0.50
ACC	0.50	1.00	0.50	1.00
CCA	0.35	0.55	0.35	0.55
CZC	0.75	1.00	0.75	1.00
CuCZA	0.50	1.00	0.50	1.00
FCAP Type A	0.35	0.50	0.35	0.50
FCAP Type B	0.35	0.55	0.35	0.55
Penetration in inches or percent of sapwood--min	2 or 85		1.5 or 85	
Determination of penetration	A borer core shall be taken from 20 pieces in each charge. If 80 percent of borings meet the penetration requirement the charge shall be accepted		A borer core shall be taken from 20 pieces in each charge. If 80 percent of borings meet the penetration requirement the charge shall be accepted.	
PRESERVATIVES	All standard preservatives listed above		All standard preservatives listed above.	

*Air seasoning is the preferred method of conditioning; however, when climatic conditions are unfavorable or delivery will be delayed because of the conditioning requirements stated above, the material may be steamed for a total of not more than eight hours at temperatures not in excess of 245° F.

Table 1 (Cont'd)-Specific Requirements for Preservative Treatment

By Pressure Processes

(Posts, Cont'd.)

17-4-16

	Lodgepole Pine		Red Pine	
CONDITIONING	Air-seasoning or steaming (for ice-coated or frozen posts only) or heating in the preservative or a combination.*		Air-seasoning or steaming (for ice-coated or frozen posts only) or heating in the preservative or a combination.*	
Steaming				
Temp.--deg F--min	...		...	
max	240		240	
Duration--hr--min	...		...	
max	3		3	
Vacuum				
Inches at sea level--min	22		22	
Duration--hr--min	½		½	
max	2		2	
Heating in preservative				
Temp.--deg F--max	220		220	
Duration--hr--max	...		...	
TREATMENT				
Expansion bath				
Temp.--deg F--max	220		220	
Pressure--lb--max	150		150	
Final Steaming				
Temp.--deg F--max	245		245	
Duration--hr--max	3		3	
RESULTS OF TREATMENT				
Retention--lb per cu ft-min				
Creosote and creosote solutions				
Creosote	6		6	
Creosote-coal tar	6		6	
Creosote-petroleum	7		7	
Oil-borne preservatives				
Pentachlorophenol	0.30		0.30	
Water-borne preservatives	Above Ground	Ground Contact	Above Ground	Ground Contact
ACA	0.30	0.50	0.30	0.50
ACC	0.50	1.00	0.50	1.00
CCA	0.35	0.55	0.35	0.55
CZC	0.75	1.00	0.75	1.00
CuCZA	0.50	1.00	0.50	1.00
FCAP Type A	0.35	0.50	0.35	0.50
FCAP Type B	0.35	0.55	0.35	0.55
Penetration in inches or percent of sapwood--min	1.25 or 85		2 or 85	
Determination of penetration	A borer core shall be taken from 20 pieces in each charge. If 80 percent of borings meet the penetration requirement the charge shall be accepted		A borer core shall be taken from 20 pieces in each charge. If 80 percent of borings meet the penetration requirement the charge shall be accepted.	
PRESERVATIVES	All standard preservatives listed above		All standard preservatives listed above	

*Air seasoning is the preferred method of conditioning; however, when climatic conditions are unfavorable or delivery will be delayed because of the conditioning requirements stated above, the material may be steamed for a total of not more than eight hours at temperatures not in excess of 245° F.

Table 1 (Cont'd.)-Specific Requirements for Preservative Treatment By Pressure Processes

(Posts, Cont'd.) 17-4-16.1

	Pacific Coast Douglas Fir	
CONDITIONING	Air-seasoning or steaming (with salt treatments only) or heating in the preservative or a combination.	
Steaming		
Temp--deg F--min	...	
max	240	
Duration--hr--min	...	
max	6	
Vacuum		
Inches at sea level--min	22	
Duration--hr--min	½	
max	...	
Heating in preservative		
Temp.--deg F--max	Seasoned; 210 and 6 hr.	
Duration--hr--max	Green or partially seasoned; 220 and no time limit.	
TREATMENT		
Expansion bath		
Temp.--deg F--max	220	
Pressure--lb--max	150	
Final Steaming		
Temp.--deg F--max	245	
Duration--hr--max	3	
RESULTS OF TREATMENT		
Retention--lb per cu ft-min		
Creosote and creosote solutions		
Creosote	6	
Creosote-coal tar	6	
Creosote-petroleum	7	
Oil-borne preservatives		
Pentachlorophenol	0.30	
Water-borne preservatives	Above Ground	Ground Contact
ACA	0.30	0.50
ACC	0.50	1.00
CCA	0.35	0.55
CZC	0.75	1.00
CuCZA	0.50	1.00
FCAP Type A	0.35	0.50
FCAP Type B	0.35	0.55
Penetration in inches or percent of sapwood--min	75% of sapwood	
Determination of penetration	A borer core shall be taken from 20 pieces in each charge. If 80 percent of borings meet the penetration requirement the charge shall be accepted.	
PRESERVATIVES	All standard preservatives listed above.	

Table 1 (Cont'd.)-Specific Requirements for Preservative Treatment By Pressure Processes

(Glued Laminated Timbers)

17-4-18.1

	Southern Pine		Pacific Coast Douglas Fir	
CONDITIONING	Since glued laminated timbers are made of preconditioned material, no seasoning before treatment is necessary.		Since glued laminated timbers are made of preconditioned material, no seasoning before treatment is necessary.	
Vacuum				
Inches at sea level--min	22		22	
Duration--hr--min	1		½	
max	3		2	
Heating in preservative				
Temp.--deg F--max	not required		210	
Duration--hr--max				
TREATMENT				
Expansion bath				
Temp.--deg F--max	not permitted		210	
Pressure--lb--max	200		150	
Final Steaming				
Temp.--deg F--max	245		240	
Duration--hr--max	3		2	
Incising	not required		required	
RESULTS OF TREATMENT				
Retention--lb per cu ft--min	General Use	Coastal Waters	General Use	Coastal Waters
Creosote and creosote solutions				
Creosote				
Under 5 in thick	10	20 lb and refusal	Refusal	Refusal
5 in and thicker	8			
Creosote-coal tar				
Under 5 in thick	10	20 lb and refusal	Refusal	Refusal
5 in and thicker	8			
Creosote-petroleum				
Under 5 in thick	10	Not recommended	Refusal	Not recommended
5 in and thicker	8			
Oil-borne preservatives				
Pentachlorophenol	0.50	Not recommended	0.50	Not recommended
Solubilized Copper 8 Quinolinolate *	0.20	Not recommended	0.20	Not recommended
	Above Ground	Ground Contact	Above Ground	Ground Contact
Water-borne preservatives				
ACA	0.30	0.50	0.30	0.50
ACC	0.50	1.00	0.50	1.00
CCA	0.35	0.55	0.35	0.55
CZC	0.75	1.00	0.75	1.00
CuCZA	0.50	1.00	0.50	1.00
FCAP Type A	0.35	0.50	0.35	0.50
FCAP Type B	0.35	0.55	0.35	0.55
Penetration in inches or percent of sapwood	2.5 or 85%		Under 5 in thick, 3/8 in or 90% of sapwood in outer 1 in. Over 5 in, 1/2 in or 90% of sapwood in outer 1 in.	
Determination of penetration	A borer core shall be taken from 20 pieces in each charge. If 80% of the borings meet the penetration requirements the charge shall be accepted.		A borer core shall be taken from the incised faces of 20 pieces in each charge. If 80% of the borings meet the penetration requirements the charge shall be accepted.	

* This preservative has the approval of the Food and Drug Administration for the preservative treatment of lumber used in areas where food is harvested, stored and transported.

Page 17–4–19

METHODS OF DETERMINING PENETRATION IN WOOD TREATED WITH PRESERVATIVES

Delete, substituting therefor the following:

1. Ammoniacal Copper Arsenite (ACA)
2. Acid Copper Chromate (ACC)
3. Chromated Copper Arsenate (CCA)
4. Chromated Zinc Chloride (CZC)
5. Copperized Chromated Zinc Arsenate (CuCZA)
6. Fluor–Chrome–Arsenate–Phenol Type A (Tanalith) (FCAP Type A)
7. Fluor–Chrome–Arsenate–Phenol Type B (FCAP Type B)
8. Solubilized Copper 8—Quinolinolate

Tests for penetration shall be in accordance with AWPA Standard A3.

Manual Recommendations

Committee 4—Rail

Report on Assignment 1

Revision of Manual

J. B. Clark (chairman, subcommittee), C. E. Weller, C. C. Herrick, C. E. Morgan, V. E. Hall, H. B. Berkshire, R. E. Catlett, Jr., J. T. Collinson, F. L. Etchison, R. G. Garland, A. V. Johnston, R. R. Lawton, A. B. Merritt, Jr., B. R. Meyers, J. S. Parsons, G. C. Payne, R. B. Rhode, H. M. Williamson.

Your committee submits for adoption the following revision to Chapter 4 of the Manual which has been approved by letter ballot to Committee 4 members.

Pages 4–2–1 to 4–2–6.1, incl.

SPECIFICATIONS FOR STEEL RAILS

On page 4–2–1 change Art. 2—Process, to read:

2. Process

The steel shall be made by one or more of the following processes: open hearth, basic oxygen or electric furnace.

Your committee also submits the following editorial changes in the Specifications for Steel Rails:

On page 4–2–2 delete "Art. 2" in third line from the top of the page and insert "Art. 3" in its place. Under 6 (d) delete "Art. 5 (c)" in each of the three paragraphs and insert "Art. 6 (c)" in its place in each paragraph. Under 7 (a) delete "Art. 5" and insert "Art. 6" in its place.

On page 4–2–3 under 7 (b), second paragraph, delete "Art. 5" and insert "Art. 6" in its place. Under 7 (c), second paragraph, delete "Art. 5" and insert "Art. 6" in its place.

On page 4–2–15, Art. 4, Ladle Analysis, paragraph (b) the words "basic oxygen" should be inserted, so as to make the paragraph read as follows:

(b) An analysis of each heat of open-hearth, basic oxygen or electric-furnace steel shall be made to determine the percentage of carbon, manganese, phosphorus, and sulfur.

Manual Recommendations

Committee 5—Track

Report on Assignment 1

Revision of Manual

C. D. Davis (chairman, subcommittee), J. E. Campbell, C. L. Gatton, A. F. Huber, G. G. Knupp, L. A. Pelton, G. H. Perkins, C. E. Peterson, J. M. Salmon, Jr., V. M. Schwing, G. R. Sproles, K. H. von Kampen, H. M. Van Syckle, M. J. Zeeman.

Your committee submits for adoption the following revisions to Chapter 5 of the Manual, which revisions have been approved by letter ballot of the committee.

Pages 5-1-1 to 5-1-3, incl.

SPECIFICATIONS FOR LOW CARBON STEEL TIE PLATES

On page 5-1-3, change Art. 9, paragraph (f), to read as follows:

"(f) Tie plates shall be accepted on the basis of actual weight as applied to the entire order, except that any weight supplied in excess of 3 percent over the weight calculated from the specified dimensions shall be the responsibility of the manufacturer."

On page 5-1-3, Change Art. 14—Rehearing, to read as follows:

"Samples tested in accordance with Art. 5 that represent rejected material shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the test, the manufacturer may request a rehearing within that time."

Pages 5-1-4 to 5-1-6, incl.

SPECIFICATIONS FOR HOT-WORKED, HIGH-CARBON STEEL TIE PLATES

On page 5-1-5, change Art. 10, paragraph (f), to read as follows:

"(f) Tie plates shall be accepted on the basis of actual weight as applied to the entire order, except that any weight supplied in excess of 3 percent over the weight calculated from the specified dimensions shall be the responsibility of the manufacturer."

Pages 5-2-1 to 5-2-3, incl.

SPECIFICATIONS FOR SOFT-STEEL TRACK SPIKES

On page 5-2-2, change Art. 10—Finish, to read as follows:

"All finished spikes shall be straight, with well formed heads, sharp points and be free from injurious defects and shall be finished in a workmanlike manner."

Add new Art. 11—Marking, reading as follows:

"11. Marking

A letter or brand indicating the manufacturer shall be pressed on the head of each spike while it is being formed. When copper is specified, the letters "CU" shall be added."

Redesignate present Art. 11—Inspection, as Art. 12—Inspection.

On page 5–2–3, redesignate Art. 12—Rejection, as Art. 13, and change to read as follows:

"13. Rejection

"(a) Material failing to meet the requirements of these specifications will be rejected.

"(b) Material that shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified."

Pages 5–2–3 to 5–2–5, incl.

SPECIFICATIONS FOR HIGH-CARBON STEEL TRACK SPIKES

On page 5–2–5, change Art. 10—Finish, to read as follows:

"All finished spikes shall be straight, with well formed heads, sharp points and be free from injurious defects and shall be finished in a workmanlike manner."

The committee has found a typographical error in Chapter 5 on page 5–6–14, Plan 10–62. The correct title of this plan is "AREA Rail Fork", and the corrected sheet will be included in the 1968 Manual Supplement.

Report on Assignment 3

Standardization of Trackwork Plans

C. J. McConaughy (chairman, subcommittee), C. R. Alberts, T. L. Biggar, W. R. Bjorklund, E. H. Blank, J. R. Bowman, L. E. Brault, J. E. Campbell, K. L. Clark, J. W. Clarke, J. P. Collins, C. D. Davis, A. D. DeMoss, L. D. Freeman, C. L. Gatton, B. J. Gordon, V. C. Hankins, C. N. Harrub, E. C. Honath, B. J. Johnson, R. A. Kelso, L. T. Klauder, R. E. Kuston, E. J. Lisy, J. G. Martin, T. D. Mason, P. R. Matthews, G. H. Maxwell, M. P. Moore, C. W. Morrison, T. C. Netherton, G. A. Payne, B. E. Pearson, C. A. Peebles, L. A. Pelton, G. H. Perkins, G. Perko, C. E. Peterson, S. H. Poore, J. A. Pollard, L. E. Porter, B. Post, R. P. Roden, J. M. Salmon, A. J. Schavet, R. N. Schmidt, V. M. Schwing, R. D. Simpson, G. R. Sproles, F. J. Swoboda, R. E. Tew, R. W. Tipper, A. C. Trimble, J. J. Vereen, K. H. von Kampen, I. V. Wiley, M. J. Zeeman.

Your committee submits for adoption the following revisions to the AREA Specifications for Special Trackwork, Appendix A of the AREA Portfolio of Trackwork Plans, which revisions have been approved by letter ballot of the committee.

Appendix A, page 5, change Article 7—Malleable Iron Castings, to read as follows:

Article 7. Malleable and Ductile Iron Castings

701. Material Covered

Iron castings for fittings and appurtenances for trackwork, braces, washers, switch-clips, spring housings and foot guards which may be produced from malleable or ductile iron at the option of the manufacturer.

702. Manufacture

(a) Iron for the castings shall be made by one of the following processes: air furnace, open hearth, or electric furnace.

(b) Malleable iron castings shall be properly annealed. Any casting rejected for improper annealing may be reannealed once.

(c) Ductile iron castings generally shall be as-cast, but may be heat treated at the option of the manufacturer.

(d) When specified in the purchase order or contract, malleable iron castings shall be manufactured in accordance with the latest revision of ASTM Specification A 47; ductile iron castings shall be manufactured in accordance with the latest revision of ASTM Specification A 536.

703. Physical Properties and Tests

(a) At the option of the purchaser or his representative, a casting may be tested to destruction, or otherwise broken up, to determine the presence of any manufacturing condition which may be detrimental to the serviceability of the casting. No other test shall be required unless otherwise specified.

(b) When so specified by the Purchaser in the order or contract, the castings shall be subject to the test prescribed in the particular ASTM specification referred to in Paragraph 702 (d). The iron shall conform to the following minimum requirements as to tensile properties:

	ASTM A 47 Malleable Grade 32510	*ASTM A 536 Ductile Grade 65–45–12*
Tensile strength, psi	50,000	65,000
Yield point, psi	32,500	45,000
Elongation in 2 in., %	10.0	12.0

704. Workmanship and Finish

(a) The castings shall conform substantially to the drawings.

(b) The castings shall be made in a workmanlike manner and shall be free from injurious defects.

Appendix A, page 7, change Article 14—Bolts and Nuts to read as follows:

Article 14. Bolts and Nuts

1401. Material Covered

(No change)

1402. Manufacture

(a) The manufacture of the bolts and nuts shall conform in general and as far as applicable to current AREA Specifications for Heat-Treated Carbon-Steel Track Bolts, and Carbon-Steel Nuts.

(b) (No change)

(a) (No change)

(b) (No change)

(c) (No change)

Heads.—American Standard square bolts (USASI B18.2.1-1965), or latest revision thereof, except where otherwise shown on detail plans.

Threads.—American Standard Unified Screw Threads, Coarse Thread Series (UNC). USASI B1.1-1960, or latest revision thereof, with tolerance and allowance in accordance with Class 2A for external threads (bolts), and Class 2B for internal threads (nuts).

Nuts.—American Standard heavy square nuts (USASI B18.2.2-1965), or latest revision thereof, made of medium carbon steel (0.40–0.55 percent C).

Fittings.—(No change)

1403. Physical Requirements

(a) (No change)

(b) (No change)

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* The stress area is the assumed area of a circle having a diameter equal to the average of the mean pitch and minor diameters with Class 3 tolerances shown in USASI B1.1—1960.

1404. Workmanship

(a) Bolts shall have unthreaded shanks within USASI B18.2.1 limits, but not less than the minimum major diameter of the threads.

(Table eliminated)

(b) When specified, bolts shall have bodies within the following dimensions:

Maximum diameter = nominal diameter +0.0
Minimum diameter = nominal diameter —0.010

In March 1966 the Association adopted the recommendation of Committee 5 to eliminate the use of rigid center frogs with angles smaller than 9 deg 35 min. Plan No. 775–55 and Plan No. 820–50 were revised accordingly and were among the plans included in the 1966 Supplement to the Portfolio of Trackwork Plans. Seven other railroad crossing plans should also have been corrected to show the minimum angle for rigid center frogs to be 9 deg 35 min, but were overlooked. These plans are: Nos. 700–55, 700J–55, 710–55, 719–55, 768–66, 769–66, 775–66.

These plans will be corrected as necessary and issued in the 1968 Supplement to the Portfolio.

Report on Assignment 9

Special Requirements of Track Construction and Maintenance Due to Operation of Equipment With High Center of Gravity and/or Hydraulically Cushioned Underframes

L. W. Green (chairman, subcommittee), C. R. Alberts, W. R. Bjorkland, E. H. Blank, J. R. Bowman, L. E. Brault, K. L. Clark, J. P. Collins, C. D. Davis, A. D. DeMoss, J. J. Eash, W. E. Griffiths, A. B. Hillman, Jr., B. J. Johnson, R. A. Kelso, C. N. King, L. T. Klauder, R. E. Kuston, R. F. Lawson, J. G. Martin, T. D. Mason, P. R. Matthews, G. H. Maxwell, T. C. Netherton, G. A. Payne, B. E. Pearson, C. A. Peebles, L. A. Pelton, C. E. Peterson, J. A. Pollard, L. E. Porter, B. Post, J. M. Salmon, Jr., A. J. Schavet, V. M. Schwing, R. W. Tipper, W. J. Wanamaker.

The tentative Manual material covering the operation on curved track of cars with high center of gravity published as information on page 365 of Bulletin 605, February 1967, is now submitted for publication in the Manual. The specific recommendation of your committee is as follows:

Pages 5–3–9 to 5–3–11, incl.

ELEVATIONS AND SPEEDS FOR CURVES

On page 5–3–11, after the second paragraph, insert the following new paragraph:

"Freight trains made up of cars with height of center of gravity not exceeding 84 in above top of rail may safely negotiate curves with 3 in unbalanced superelevation.

For trains containing cars with height of center of gravity between 84 and 100 in above top of rail it is recommended that the speed be restricted to that which will provide for a maximum of 2 in unbalanced superelevation. For trains containing cars with height of center of gravity between 100 and 110 in above the top of rail it is recommended that the speed be restricted to that which will provide for a maximum of 1 in unbalanced superelevation. For trains containing cars with height of center of gravity exceeding 110 in it is recommended that the speed be restricted to equilibrium speed."

Manual Recommendations

Chapter 7—Wood Bridges and Trestles

Report on Assignment 5

Design of Structural Glued Laminated Wood Bridges and Trestles

J. A. Gustafson (chairman, subcommittee), Billy Bohannan, James Budzileni, T. P. Burgess, J. W. Chambers, B. E. Daniels, S. L. Goldberg, E. E. Gordon, R. W. Gunther, F. J. Hanrahan, J. M. Helm, J. F. Holmberg, B. J. King, R. E. Kuehner, T. K. May, J. W. N. Mays, D. H. McKibben, W. A. Oliver, G. N. Sells, L. E. Titlow, S. J. Zajchowski.

Your committee submits for adoption the following recommendations with respect to Chapter 7 of the Manual:

Pages 7-1-42 to 7-1-56, incl.

SPECIFICATIONS FOR GLUED LAMINATED LUMBER

Delete the text on page 7-1-42 through page 7-1-48, substituting therefor the following revised version:

1. General

a. The term "Structural Glued Laminated Timber" as employed herein refers to an engineered, stress-rated product of a timber laminating plant, comprising assemblies of suitably selected and prepared wood laminations securely bonded together with adhesives. The grain of all laminations is approximately parallel longitudinally. The separate laminations shall not exceed 2 in. in net thickness. They may be comprised of pieces end joined to form any length, of pieces placed or glued edge to edge to make wider ones, or of pieces bent to curved form during gluing.

b. Laminations shall be arranged horizontally (wide face of laminations placed normal to the direction of the load) in members stressed principally in bending, except as hereinafter provided.

c. Except as otherwise provided, glued laminated member shall be designed in accordance with the engineering formulas used for solid sawn wood members and those presented in Appendix A. (For more detail, see Fabrication and Design of Glued Laminated Wood Structural Member, Technical Bulletin No. 1069 of U. S. Department of Agriculture; National Design Specification for Stress-Graded Lumber and Its Fastenings, by the National Forest Products Association; and Timber Construction Manual, by the American Institute of Timber Construction.)

d. The same allowable loads and methods of design for bolts, connectors, and other fastenings apply to glued laminated members as to solid sawn members. (For more detail, see the Timber Construction Manual and National Design Specifications noted above.)

e. Except as otherwise provided, U. S. Commercial Standard CS 253-63 for Structural Glued Laminated Timber is adopted as a part of this specification.

2. Design Stresses

a. Allowable stress values for dry conditions of use shall be applicable for normal loading and long duration of loading when the moisture content in service is less than 16 percent, as in most covered structures.

b. Allowable stress values for wet conditions of use as shown in tables shall be applicable for normal loading and long duration of loading when the moisture content in service is 16 percent or more, as may occur in exterior and submerged construction.

c. The allowable stresses for wet and dry conditions of use of structural glued laminated timber that has been pressure impregnated by an approved process and preservative may be reduced in accordance with the railroad's practice.

d. Any purchase specification predicated on a stress level that is common to dry and wet conditions of use without indicating the applicable basis shall be interpreted as being based on dry conditions of use for soft woods, and based on wet conditions of use for hardwoods.

3. Sizes for Laminations

a. Individual laminations shall be 2 in. net or less in thickness.

b. To the extent that practical considerations will permit, all laminations of each individual member shall be of the same uniform thickness. When laminations of different thicknesses are used, divide the depth of the member by the thickness of the thickest lamination used and then assume the quotient to be the number of laminations in the member in determining the allowable stress.

c. For exterior use, face laminations of a member shall be of one piece in width or of pieces pre-glued together edgewise.

4. Grade Provisions

a. All lumber used as laminations in the fabrication of structural glued laminated lumber shall be graded in accordance with the current Standard Grading Rules and with additional requirements as herein specified.

b. The lumber used for laminations shall be uniformly manufactured and shall be as required by Tables 1, 2, 3, 4, 5, and 6, except as modified herein.

c. When lumber to be used for laminating is re-sawn, the finished re-sawn size shall meet the grade requirements.

5. Slope of Grain

a. Slope of grain shall be limited in the full length of each lamination and shall be measured over a distance sufficiently great to determine the general slope, disregarding slight local deviations resulting from permissible defects.

b. Slope of grain shall be limited in bending stress as indicated in Tables 7 and 8, except for members specified as being stressed principally in compression or tension, in which case the limitation shall apply as indicated for compression or tension stress, as the case may be.

6. Vertical Laminations

a. When vertically laminated beams are specified, the allowable stresses shall be the stresses specified in the proper table.

b. When other information is not available, the stress as specified in the Standard Grading Rules for the grade of lumber may be used.

c. Allowable stresses for vertically laminated beams made up of combination grades of lumber shall be the weighted average of the lumber grades.

7. Radius of Curvature

a. For minimum radius see recommended practice of manufacturers.

8. Finished Sizes

a. Net (not nominal) dimensions of members shall be specified.

b. All members shall be trimmed to the length and finished to the width and depth dimensions specified. Net dimensions shall be specified. Standard finished width of laminated members shall be as follows:

Nominal width, inches	3	4	6	8	10	12	14	16
Net finished width, inches	2¼	3¼	5 or 5¼	7	9	11	12½	14½

c. Members that are specified to be pressure impregnated with a preservative after lamination shall be finished to size, and all cutting, framing, and boring of timbers shall be done before treatment, unless otherwise specified.

d. Should water-borne preservatives be used, special consideration should be given to dimensional change.

9. Marking and Wrapping

a. Each completed member shall be certified and marked with the product quality mark of Commercial Standard CS 253–63 unless otherwise specified by the purchaser.

b. Each completed member that is stressed principally in bending, if significant to its proper use, shall be plainly marked to identify its top and bottom face.

c. Requirement for end sealing protection from damage during shipment shall be specified for the member involved.

d. Each completed member shall be protected from damage such as would noticeably impair its appearance or lower its strength, durability or utility values. When method of shipment warrants such protection, a wrapping to enclose each completed member may be required.

e. Each completed member, if not pressure impregnated with a preservative and if the weather or other conditions justify, may be required to be enclosed in a moisture-resistant wrapping or coating.

f. It shall be the responsibility of the Contractor to provide protection on the job site.

STANDARD REFERENCES

a. U. S. Department of Commerce, "Commercial Standard CS 253–63 Structural Glued Laminated Timber" (available from Superintendent of Documents U. S. Government Printing Office).

b. "Timber Construction Manual," by American Institute of Timber Construction, John Wiley and Sons, Inc., 1966.

c. U. S. Department of Agriculture Technical Bulletin 1069, "Fabrication and Design of Glued Laminated Wood Structural Members," by A. D. Freas and M. L. Selbo, Forest Products Laboratory (presently out of print).

d. Current "National Design Specification for Stress-Grade Lumber and Its Fastenings," National Forest Products Association.

e. American Institute of Timber Construction, "Timber Construction Standards AITC 100–65."

f. Current "Standards for Structural Glued Laminated Members Assembled with Douglas Fir and Larch Lumber," Western Wood Products Association.

g. Current standard specifications for "Design" and "Fabrication" of "Structural Glued Laminated West Coast Hemlock Lumber," West Coast Lumbermen's Association.

h. Current "Standard Specifications for Structural Glued Laminated Southern Pine Timber," Southern Pine Inspection Bureau.

i. Current "Standard Specifications for the Design and Fabrication of Hardwood Glued Laminated Lumber for Structural, Marine and Vehicular Uses," Southern Hardwood Producers, Inc., Appalachian Hardwood Manufacturers, Inc., and Northern Hemlock and Hardwood Manufacturers Association.

j. Current "Standard Specification Structural Glued Laminated California Redwood Timber," California Redwood Association.

k. Current "Standard Specification for Structural Glued Laminated Douglas Fir Timber," West Coast Lumbermen's Association.

APPENDIX A

1. Supplementary Design Provisions

a. "Normal" load duration means fully stressing a member to its allowable stress by the application of the full maximum normal design load for a period of approximately 10 years (either continuously or cumulatively during the life of the structure). Periods of loading when the stress is less than 90 percent of the allowable stress for normal loading need not be counted in accumulating the 10-year period.

b. When the duration of full design load does not exceed the period indicated above, the tabulated allowable stress for normal loading conditions may be increased by any one of the following:

15% for two months' duration
25% for seven days' duration
33⅓% for wind or earthquake

c. Occasional impact may be disregarded it the stress induced by it does not exceed the allowable stress for normal loading.

d. Modulus of elasticity is assumed a constant and none of the foregoing adjustment apply.

2. Curvature Factor

a. For the curved portion of a member, the allowable stress in bending shall be multiplied by the curvature factor:

$$1 - 2{,}000\left(\frac{t}{R}\right)^2$$

in which:

t = the thickness of lamination in inches, and

R = the radius of curvature of a lamination in inches, and t/R shall not exceed 1/100 for hardwoods and Southern pine, nor 1/125 for softwoods other than Southern pine. No curvature factor shall be applied to stress in the straight portion of a member regardless of curvature elsewhere.

3. Radial Tension or Compression

a. The maximum radial stress induced in a curved member of rectangular cross section by a bending moment is:

$$f_r = \frac{3M}{2Rbh}$$

in which:

f_r = radial stress in pounds per square inch
M = bending moment in inch-pounds

R = radius of curvature at center line of member in inches
b = width of member in inches
h = height of member in inches

b. When M is in the direction tending to decrease curvature (increase the radius), the radial stress is in tension and shall be limited in accordance with the regional lumber association specifications for structural glued laminated timber, except in the case of Douglas fir which shall be limited to 15 psi. Generally, this allowable stress in tension is limited to one-third the allowable stress in horizontal shear.

c. When M is in the direction tending to increase curvature (decrease the radius), the radial stress is in compression and shall be limited to the allowable stress in compression perpendicular to the grain.

Manual Recommendations

Committee 8—Masonry

Report on Assignment 1

Revision of Manual

W. R. Wilson (chairman, subcommittee), R. J. Brueske, G. W. Cooke, W. P. Hendrix, F. A. Kempe, Jr., E. D. Ripple.

Your committee submits the following minor revisions, due to changes in ASTM specification references, for adoption and publication in the Manual.

Pages 8–1–1 to 8–1–32, incl.

SPECIFICATIONS FOR CONCRETE AND REINFORCED CONCRETE RAILROAD BRIDGES AND OTHER STRUCTURES

Page 8–1–9, Sec. E, Art. 2—In the last line, change A 7 to A 36

Pages 8–17–1 to 8–17–24, incl.

SPECIFICATIONS FOR DESIGN, MATERIALS AND CONSTRUCTION OF PRESTRESSED CONCRETE STRUCTURES

Page 8–17–17, Sec. Q, Art. 2—Delete "Standard Specifications for Portland Blast Furnace Slag Cement (ASTM Designation C 205)" and "Standard Specifications for Portland-Pozzolan Cement (ASTM Designation C 340)."

Add "Standard Specifications for Blended Hydraulic Cement (ASTM Designation C 595)."

Report on Assignment 7

Quality of Concrete and Mortars

W. P. Hendrix (chairman, subcommittee), H. C. Brown, N. D. Bryant, J. W. Dolson, Conrad W. Hale, G. P. Hayes, Jr., H. W. Hopkins, A. K. Howe, R. J. Klueh, R. E. Kuban, G. F. Leyh, J. M. Williams, S. G. Wintoniak.

Your committee offers for adoption the following editorial revisions with respect to Chapter 8 of the Manual.

Pages 8–20–1 to 8–20–3, incl.

ASTM SPECIFICATIONS AND DESIGNATIONS

A 6–65, change to A 6–67

A 7–65, delete

A 15–65, change to A 15–66

A 16–65, change to A 16–66
A 36–67 Structural Steel, add to list to replace A 7 deleted.
A 82–65, change to A 82–66
A 160–65, change to A 160–66
A 408–65, change to A 408–66
A 431–65, change to A 431–66
A 432–65, change to A 432–66
C 29–60, change to C 29–67T and add "(Tentative)" after title.
C 33–66, change to C 33–67
C 76–66T, change to C 76–67. and delete "(Tentative)" from title.
C 87–63T, change to C 87–67T
C 91–66, change to C 91–67
C 117–62T, change to C 117–67, and delete "(Tentative)" from title.
C 136–63, change to C 136–67
C 142–66T, change to C 142–67 and delete "(Tentative)" from title.
C 150–66, change to C 150–67
C 175–66, change to C 175–67
C 205–64T, delete
C 227–65, change to C 227–67
C 290–63T, change to C 290–67, and delete "(Tentative)" from title.
C 291–61T, change to C 291–67, and delete "(Tentative)" from title.
C 340–66T, delete
C 342–65, change to C 342–67
C 595–67T, Blended Hydraulic Cement (Tentative), add to list to replace C 205 and C 340 deleted.
D 15–64T, change to D 15–66T
D 395–61, change to D 395–67
D 573–53, change to D 573–67

Manual Recommendations

Committee 9—Highways

Report on Assignment 1

Revision of Manual

M. A. Wohlschlaeger (chairman, subcommittee), G. B. Blatt, W. B. Calder, L. T. Cerny, C. A. Christensen, F. R. Cummings, F. C. Cunningham, C. L. Holman, H. A. Hunt, R. W. Mauer, C. B. May, E. S. Miller, D. J. Moody, R. E. Skinner, C. H. Stephensen, W. S. Titlow, Jr., J. M. Trissal.

Recently the Grade Crossing Protection Committee of the Train Operation, Control and Signal Committee, Association of American Railroads, published an Addendum to Bulletin 6 dated January 17, 1967. Your committee has approved, by letter ballot, certain revisions in Chapter 9 of the AREA Manual as necessary to conform with this Addendum.

Your committee has also approved, by letter ballot, certain modifications to "General Specifications for Highway Grade Crossing over Railroad Tracks," pages 9–1–2 and 9–1–3 of the Manual.

Following are the specific recommended revisions to Chapter 9:

Pages 9–1–2 and 9–1–3

GENERAL SPECIFICATIONS FOR HIGHWAY GRADE CROSSINGS OVER RAILROAD TRACKS

Art. 1—Width of Crossing. Entire text to be rewritten as follows:

"The crossing shall be of such width as prescribed by law, but in no case shall the width be less than that of the adjacent roadway."

Art. 2—Profile of Crossing and Approaches; change heading to read: "Profile and Alignment of Crossing and Approaches."

Add second paragraph to text reading as follows:

"If practicable, the highway alignment should be such as to intersect the railroad track at or nearly at right angles."

Art. 3—Width and Surfaces of Approaches; change heading to read:

"Width and Marking of Approaches."

Entire text to be rewritten as follows:

"Width of roadway at a highway-railway grade crossing should correspond to that of the adjoining highway and have the same number and width of traffic lanes as adjoining highway without extra lanes at the crossing.

At all paved approaches to the highway-railway grade crossing, the highway traffic lanes in the vicinity of the crossing should be distinctly marked in accordance with the recommendations of the Manual on Uniform Traffic Control Devices for Streets and Highways. Such markings are the responsibility of the public authorities.

Art. 7—Rail; delete the word "new", which is the third word in the second line of the text.

Art. 8—Flangeway Widths; insert the words "at least" between the words "be" and "2 in." in second line of text.

Art. 9—Choice of Material for Crossing; insert period behind word "located" in first line of second paragraph of text, and delete the second line of the second paragraph.

The following recommended revisions are necessary to make Chapter 9 conform with Bulletin 6.

Pages 9–3–2 to 9–3–2.2, incl.

SPECIFICATIONS FOR HIGHWAY GRADE CROSSING SIGNALS

On page 9–3–2.2, insert a new article, as follows:

9. Guard Rails

Where practicable, and the public authorities so request, suitable guard rails may be installed in advance of the signals. Such guard rails are the responsibility of the public authorities.

Pages 9–3–4 through 9–3–15, Figs. 1 through 12—Revise the drawings to indicate dimension from center of signal to edge of pavement as 6′ minimum.

Page 9–3–16, Fig. 13—Revise drawing as follows:

a. Change lateral dimension from curb to center line of signal from 3 ft 0 in to 4 ft 1 in.

b. Change clearance dimension from 11 in to 2 ft.

c. Change note on plan to read: "On some types of gates the gate arm extends out beyond the background 3 inches, which necessitates 2 feet 3 inches instead of 2 feet shown on the drawing."

Changing the lateral dimension to 4 ft 1 in on Fig. 13 necessitates increasing the minimum width of the median strip for divided highways on Fig. 7, page 9–3–10; Fig. 8, page 9–3–11; Fig. 9, page 9–3–12; Fig. 11, page 9–3–14; and Fig. 12, page 9–3–15.

Change the "6′ Minimum" median width shown on these figures to read "8′ 2″ Minimum—See note on Fig. 13."

Page 9–3–13, Fig. 10—change the "Less than 6′ ″ median width to "Less Than 8′-2″."

Your committee recommends approval by the Association of the above Manual changes.

Manual Recommendations

Committee 14—Yards and Terminals

Report on Assignment 1

Revision of Manual

G. H. Chabot (chairman, subcommittee), R. N. Arrington, A. E. Biermann, W. O. Boessneck, A. L. Carpenter, M. K. Clark, J. A. Comeau, G. H. Dayett, Jr., T. R. Dushel, C. M. Frazier, W. H. Goold, H. R. Hall, Wm. J. Hedley, J. E. Hoving, D. B. Kendall, E. T. Lucey, L. L. Lyford, G. W. Mahn, Jr., H. J. McNally, C. H. Mottier, B. G. Packard, M. B. Parker, L. J. Riekenberg, L. W. Robinson, S. L. Staples, C. E. Stoecker, T. DeW. Styles, L. L. Tameling, L. G. Tieman, B. H. Voor, Jr., W. E. Webster, Jr.

Your committee submits for adoption the following recommendations with respect to Chapter 14 of the Manual.

Pages 14–2–1 to 14–2–19, incl.

PASSENGER TERMINALS

Reapprove with the following revision:

On page 14–2–16, in subparagraph (i) 2, add after the word "clips" in the third line, "however, better results will generally be experienced with rails installed on bearing plates and cushions", thus making the second sentence read: "The rails can rest directly on the concrete walls, if desired, without plates and cushions, and be anchored in place by bolted down rail clips; however, better results will generally be experienced with rails installed on bearing plates and cushions."

Pages 14–4–1 to 14–4–11, incl.

LOCOMOTIVE TERMINALS

Reapprove with the following revisions:

On page 14–4–8, in Sec. E. MISCELLANEOUS FACILITIES, insert a new Art. 6 to read:

"6. Fueling Stations

In the design and construction of fueling stations at diesel, diesel–electric and electric locomotive terminals, provisions should be included to prevent the pollution and contamination of public waters from spilled fuels and oils through surface and subsurface waters, sewers and other conduits."

Renumber present Art. 6 on page 14–4–8 as Art. 7 and Arts. 7 and 8 on page 14–4–9 as Arts. 8 and 9, respectively.

Manual Recommendations

Committee 15—Iron and Steel Structures

Report on Assignment 1

Revision of Manual

E. S. Birkenwald (chairman, subcommittee), T. J. Boyle, J. L. Durkee, G. F. Fox, E. T. Franzen, T. J. Mearsheimer, D. V. Messman, R. D. Nordstrom, D. D. Rosen, G. W. Salmon, R. D. Spellman, J. E. Stallmeyer.

Your committee submits the following revisions of specifications for adoption and publication in the Manual:

Pages 1–4–25 to 1–4–32, incl.

SPECIFICATIONS FOR CORRUGATED STRUCTURAL PLATE PIPE, PIPE-ARCHES, AND ARCHES

Page 1–4–26, Art. 4, Sec. B: Substitute the following:

4. Physical Properties

The minimum physical properties of the flat sheet or plate before corrugation shall be as follows:

Tensile strength, psi	42,000
Yield point, psi	28,000
Elongation in 2 in, percent	30

The supplier shall certify that the tests performed on each heat of the material furnished meet the above requirements.

Page 1–4–28, Sec. D: Insert a new Art. 1, as follows:

1. Foreword

For Cooper E 80 live load, gage and bolting requirements may be determined from Table 4. For live load other than Cooper E 80, the design shall be as outlined below.

Page 1–4–28, Art. 1, Sec. D: Change the article number from 1 to 2.

Page 1–4–28, present Art. 1.a, changed to Art. 2.a, Sec. D: In the second line, change 100 to 120.

Page 1–4–28, present Art. 1.b, changed to Art. 2.b, Sec. D: Substitute the following:

b. Live Load and Impact

Live load shall be Cooper E 80, unless otherwise designated by the Engineer and shall include an allowance of 50 percent of the live load for impact.

Change the table heading under new Art. 2b to read:

TABLE 1—LIVE LOADS, INCLUDING IMPACT, FOR VARIOUS HEIGHTS OF COVER FOR COOPER E 80*

In this table, change the values for the load as follows:

Height of Cover (Ft)	*Load (Lb/Ft^2)*
2	3,800
5	2,400
8	1,600
10	1,100
12	800
15	600

Substitute the following for the note below this table:

*If height of cover (from bottom of cross tie to top of structure) is over 30 ft, use dead load only. For live load other than Cooper E 80, the above values should be accordingly adjusted.

Page 1–4–28, new Art. 2.c, Sec. D: Change "Table 1" to read "Table 2."

Page 1–4–28, new Art. 2.d, Sec. D: Change "Table 1" to read "Table 2."

Page 1–4–29, TABLE 1, Sec. D: Change TABLE 1 in the table heading to TABLE 2; and Table 2, in the parentheses in the definition of *I,* to Table 3.

Page 1–4–29, TABLE 2, Sec. D: Change TABLE 2 in the table heading to TABLE 3.

Page 1–4–30, Art. 2, Sec. D: Change the article number from 2 to 3.

Page 1–4–30, Art. 3, Sec. D: Change the article number from 3 to 4.

Page 1–4–30, TABLE OF MINIMUM AND MAXIMUM HEIGHT . . ., Sec. D:
Insert this table between new Art. 2.f, and new Art. 3.

Change the heading of this table to read:

TABLE 4—MINIMUM AND MAXIMUM HEIGHT OF COVER IN FEET FOR COOPER E 80 LIVE LOAD INCLUDING IMPACT

In this table, change the values for minimum height of cover as follows:

Equivalent Dia. in Feet	*12 Ga.*	*10 Ga.*	*8 Ga.*	*7 Ga.*
7	4			
9	7			
10	8			
13		6		
14		8		
15		9		
18			7	
19			8	6
20				7
21				8

Below this table in the Notes, first line, change 4 to 3.33.

Page 1–4–30, Art. 4, Sec. D: Change the article number from 4 to 5.

Page 1–4–31, Art. 5, Sec. D: Change the article number from 5 to 6.

Manual Recommendations

Committee 20—Contract Forms

Report on Assignment 2

Form of Agreement to Cover Experimental Demonstration of Equipment and Materials on Railway Company Property

C. G. NELSON (chairman, subcommittee), W. F. BURT, J. C. BRITT, A. P. FISH, E. A. GRAHAM, R. W. HUMPHREYS, D. F. LYONS, J. L. PERRIER, C. W. SMITH, W. B. TITTSWORTH, JR.

A form of this agreement was prepared last year and published in Bulletin 602, Proceedings Volume 68, pages 177 to 180, incl. The report was submitted as information with an invitation to the Association for comment and criticisms.

The report as originally printed required some minor corrections, and your committee recommends that the agreement as corrected be accepted as Manual material and be printed in the Manual in Chapter 20, Part 7.

FORM OF AGREEMENT TO COVER EXPERIMENTAL DEMONSTRATION OF EQUIPMENT AND MATERIALS ON RAILWAY COMPANY PROPERTY

THIS AGREEMENT, made this ...... day of ...., 19 ...., by and between ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company, and ...., hereinafter called the Licensee.

WITNESSETH:

WHEREAS, the Railway Company is the owner of certain facilities and properties located in or near ...., State of ...., and further described as follows: ...., and hereinafter referred to as the Premises, and as shown on Exhibit "A" dated ...., 19 ...., attached hereto and made a part hereof, and

WHEREAS, the Railway Company desires to use modern and economical equipment and materials for construction and maintenance of railway facilities, and

WHEREAS, the Licensee is the supplier of equipment and materials used in the construction and maintenance of railway facilities, and

WHEREAS, the Licensee desires to enter upon the Premises of the Railway Company for purposes of making experimental demonstrations including tests of the items of equipment and materials as itemized in Exhibit "B", dated ...., 19 ...., attached hereto and made a part hereof;

NOW, THEREFORE, in consideration of the mutual covenants and conditions herein stipulated, to be kept by the parties hereto, it is agreed as follows:

1. Right of Entry

The Railway Company hereby grants permission to the Licensee to enter onto the Premises for purposes of making experimental tests and demonstrations of items of equipment and materials as listed in Exhibit "B". It is expressly noted that this is limited to the legal right of the Railway Company to make such a grant.

2. Notification

The Licensee shall give the .... of the Railway Company not less than .... notice before entering upon the Premises.

3. Ownership and Maintenance

Except as hereinafter specified, the said equipment and materials are, and shall remain the property of the Licensee, and shall be maintained by the Licensee at its sole risk, cost and expense and in a manner that will not impair the safe operations of the Railway Company. Upon completion of the experimental tests and demonstrations, materials that remain as a part of the Premises shall become the property of the Railway Company.

4. Transportation and Installation

Except as hereinafter specified, the entire cost and expense of loading, transporting, unloading, installing, providing utility connections, and all other costs incurred in connection with the handling of the equipment and materials shall be borne entirely by the Licensee. The Railway Company agrees to furnish free transportation on and over its lines, insofar as it may lawfully do so, for representatives and employees of the Licensee directly engaged in the aforesaid tests and demonstrations, and free transportation on and over its lines for tools, equipment, supplies and materials required in connection therewith.

5. Operation and Maintenance

The Licensee shall provide qualified and competent operators, operator–instructors, mechanics, miscellaneous personnel and supervisors as may be necessary and shall furnish materials and supplies to keep the demonstration equipment properly maintained and in safe and good working order, all without expense to the Railway Company.

6. Supervision and Protection

It is understood that all activities on the Premises shall be conducted subject to supervision of Railway Company personnel. Supervision shall be furnished at no expense to the Licensee. When the Railway Company deems it necessary to provide protection, the expense of such protection shall be furnished at no expense to the Licensee.

7. Independent Contractor

It is expressly understood and agreed that the Licensee is and shall be deemed an independent contractor and that the Railway Company reserves no control whatsoever over the employment, discharge, compensation of, or services rendered by, the employees of the Licensee.

8. Tests

It is agreed that the results of any physical or laboratory test or tests made by either party to this agreement in connection with the demonstrations shall be furnished without cost to the other party upon request.

9. Photographs

It is agreed that either party may photograph, film or otherwise reproduce on paper or other material, the Licensee's equipment and materials and the Premises of the Railway Company during the course of the tests and demonstrations. Such films, photographs or other reproductions shall not be publicized without the mutual consent of both parties, which consent shall not be unreasonably withheld.

10. Laws, Permits and Taxes

The Licensee shall, at its sole cost and expense, procure all necessary consents and permits from all public authorities having jurisdiction, and shall pay all license fees and taxes, or increase of taxes, assessed against or imposed on or by reason of said experimental tests and demonstrations, and at all times during the continuance hereof, shall comply with all rules, regulations and requirements of said authorities.

11. Patented Devices

In the event the Licensee shall make use of or employ any patented devices or materials for carrying out the tests and demonstrations, the Licensee shall satisfy all claims or charges for lease, privilege or royalty, and shall at its sole expense defend the Railway Company against any and all claims and suits which may arise from any infringement of patent rights, and indemnify and save harmless the Railway Company against any judgment of recovery as a result thereof.

In the event any claims or suits are brought against the Railway Company from any infringement of patent rights, the Railway Company will immediately transmit to the Licensee the name and address of the claimant, the nature of the claim, and such other information as may be applicable to such claim.

12. Pilferage and Damage

The Railway Company shall not be held responsible or accountable for the safety or care of the equipment or materials.

13. Indemnity

The Licensee shall protect, indemnify and save harmless the Railway Company and any other corporation or person on the Premises from and against any and all loss or damage to property or injury to or death of person or persons, and all suits, claims, liabilities or demands in connection therewith, howsoever caused, resulting directly or indirectly from the operations of the Licensee in performing the tests and demonstrations.

14. Unemployment and Retirement Legislation

The Licensee shall accept full and exclusive liability for the payment of any and all contributions or taxes for unemployment insurance or old age retirement benefits, pensions and annuities now or hereinafter imposed by the Government of the United States or of any State thereof, which are measured by the wages, salaries or other remunerations paid to persons employed by the Licensee.

15. Insurance

The Licensee shall at its own expense carry insurance at all times in a company or companies approved by the Railway Company, covering the liability assumed under this agreement, with limits of not less than $...................... for one person and $.......................... for one accident for personal injuries or death, and $......................... for property damage for each accident with an aggregate limit of not less than $......................, and shall furnish the Railway Company true original counterparts of such policy or policies and have the written approval of the Railway Company of said policies at least forty-eight hours before starting any work covered by this agreement. Said policies shall provide for notice to the Railway Company at least .... days in advance of cancellation or change.

16. Restoration

The Licensee shall, upon completion of the tests and demonstrations, restore the Premises to its original condition or a condition satisfactory to the .... of the Railway Company. It is understood if Licensee should fail in any instance to withdraw promptly any equipment or materials from the Premises after receipt of notice from Railway Company so to do, Railway Company may, at its option, and without further notice to Licensee, and as agent of Licensee, place such equipment or materials in storage on its own property or on the property of others, for and on account of Licensee, and Licensee agrees to pay the cost thereof.

17. Term

This agreement shall terminate as of .... However, either party hereto may terminate this agreement at any time by giving to the other party .... notice in writing to this effect. Such termination shall not be construed as relieving the Licensee of any obligations or liability incurred prior to such termination.

18. Assignment

Licensee will not assign or transfer this agreement, in whole or in part, without the written consent of the Railway Company.

The covenants, conditions, terms and agreements herein contained shall inure to the benefit of and be binding upon the legal representatives of the parties respectively.

In Witness Whereof, the parties hereto have executed this agreement in .... on the day and year first above written.

Witness:

....Railway Company

By..........................

Witness: ....

.... By..........................

Report on Assignment 3

Form of Agreement for Handling Truck Trailers and Containers at Terminals

J. D. Taylor (chairman, subcommittee), J. F. Bruckner, Jr., W. F. Burt, A. B. Costic, E. A. Graham, R. C. Heckel, R. P. Hoffman, J. W. Rach, C. W. Smith.

In Bulletin 609, November 1967, it was indicated on page 179 under Assignment 3 that a Form of Agreement for Handling Truck Trailers and Containers at Terminals, would be submitted for adoption and publication in the Manual and would be published with the Manual recommendations in Part 2 of Bulletin 610, December 1967. However, after publication of the November Bulletin, the committee decided to publish the agreement form as information this year, looking to submitting it for adoption next year.

Hence, the following agreement form is submitted as *information only,* not for adoption and publication in the Manual.

FORM OF AGREEMENT FOR HANDLING TRUCK TRAILERS AND CONTAINERS AT TERMINALS

THIS AGREEMENT, made this .... day of ...., 19 ...., between ...., a corporation organized under the laws of the state of ...., hereinafter called the "Railway Company", and .... hereinafter called the "Contractor".

Witnesseth:

Whereas, the Contractor is engaged in the business of transportation in and about ...., by means of motor trucks, trailers, and other suitable equipment, and

Whereas, the Railway Company proposes to establish a service for the handling of trailers and containers on railroad cars and desires to obtain the services of the Contractor in handling the trailers and containers within the area of ...., hereinafter sometimes referred to as "Area", in accordance with the applicable tariffs of Railway Company, which services the Contractor is willing to supply on the terms and conditions hereinafter stated;

Now, Therefore, in consideration of the mutual covenants and conditions herein stipulated to be kept by the parties hereto, it is hereby agreed as follows:

1. Description

The Railway Company shall provide suitable loading and unloading facilities, and shall perform the necessary switching of cars at said facilities.

The Contractor, when notified by authorized representative of the Railway Company, shall furnish all necessary labor, materials and equipment for the prompt loading and unloading of trailers and containers onto and off of cars of the Railway Company at said loading and unloading facilities; also, to pick up and deliver loaded and empty trailers and containers of Railway Company in said Area as directed by Railway Company.

2. Compensation

For the services rendered by the Contractor pursuant to this agreement, the Railway Company shall pay the Contractor in accordance with Schedule "A", dated ...., hereto attached and made a part hereof.

Bills shall be rendered by the Contractor against the Railway Company on or before the .... day of each month for compensation earned during the previous calendar month and shall be supported by statements setting forth the data upon which the amounts due are calculated in sufficient detail so that the bills can be checked. The Contractor shall, on request, furnish such information as may be required by the Railway Company to determine the starting and terminating time for periods in which service is performed. All payments due the Contractor shall be made not later than the .... day of each month for the business transacted during the next preceding calendar month. The books and records of the Contractor shall be open to inspection by the Railway Company at all reasonable times for the verification of Contractor's bills.

3. Receipts

The Contractor shall give receipts to shippers for all shipments received, furnish the Railway Company with copies thereof, and shall take receipts, in duplicate, from all consignees for shipments delivered and give a copy of such receipts to the Railway Company. Receipts shall be on forms prescribed by the Railway Company and shall carry notations as to the apparent condition of the freight, trailers and containers at the time of receipt or delivery if in other than good condition. Subject to instructions from the Railway Company, no deliveries of freight shipped on order bills or on straight bills of lading subject to delivery orders shall be made by the Contractor until after the original order bill of lading, or delivery order, properly endorsed, has been surrendered to the Contractor. The Contractor shall promptly deliver to the Railway Company all such original bills of lading and delivery orders, properly endorsed, surrendered by any consignees on delivery of any freight handled hereunder.

4. Collections

When requested so to do, the Contractor shall collect and pay to the Railway Company's agent, on the same day collected if feasible, but in no event later than noon of the next succeeding business day, all charges on inbound freight and all charges from consignors on outbound freight billed prepaid and C.O.D. shipments. The Contractor shall furnish receipts for any sums so collected on forms and in the manner prescribed by the Railway Company. Should the Contractor be unable to make such collections on inbound freight, the Contractor shall return the shipment to the Railway Company at point designated by its agent, and receipt shall be given to the Contractor therefor. All collections shall be made in cash unless otherwise authorized in writing by the Railway Company. The Contractor in no case shall be liable for the payment of checks or forms of payment other than cash accepted by Contractor under such written authorization. In the event the Contractor violates the provisions of this section, the Contractor shall be directly responsible to the Railway Company for such freight charges, and the Railway Company will in such case deduct such charges from any amounts due the Contractor hereunder.

5. Liability

Contractor covenants and agrees to protect, indemnify, and hold harmless the Railway Company from and against any and all loss, damage, cost, and expense, including attorneys' fees, that may be suffered or incurred by the Railway Company or by any person or persons, firm, association, or corporation resulting from:

(a) Injury to or death of all persons, including employes of the parties hereto, loss or destruction of or damage or delay to property, including the property of and in the custody of the parties hereto, including the conversion thereof, caused by or resulting in any manner from any acts or omissions, negligent or otherwise, of Contractor or any of Contractor's agents, servants, or employes in performing or failing to perform any of the services or duties on the part of the Contractor to be performed hereunder;

(b) The issuance of any false or fraudulent bill of lading or delivery order, or the giving or receiving of any false or fraudulent receipt or delivery order for any freight or for freight charges by the Contractor or any of the Contractor's agents or employes;

(c) Failure of the Contractor or any of the Contractor's agents or employes to make collections and remittances to the Railway Company as provided in this agreement, or to take up and deliver to the Railway Company order bills or delivery orders as provided in Section 3 and

(d) Theft, embezzlement, or defalcation on the part of the Contractor or any of the Contractor's agents or employes.

6. Insurance

The Contractor, at its own cost and expense, shall procure prior to commencement of any work under this agreement and shall maintain in full force and effect at all times during the continuance of this agreement, insurance of the following kinds and amounts, in such form and issued by such insurance companies as shall be satisfactory to Railway Company:

(a) Workmen's Compensation insurance which fully meets the requirements of any Workmen's Compensation law in force at the place where the work is to be performed, including the requirements of any Occupational Disease Law, and Employers' Liability insurance with limits of not less than $......................

(b) Comprehensive General Liability insurance (including Automobile Liability) with limits for bodily injury, including death, of not less than $........... for one person and not less than $............. for all persons arising out of each occurrence, and limits of not less than $............. for damage to or destruction of property, including the loss of use thereof, for each occurrence, and not less than $.............. in the aggregate. Such insurance shall include coverage for contractual liability assumed by Contractor under this Agreement, with specific reference made thereto, and shall also cover the legal liability of Contractor and Railway Company when towing trailers and containers which are not owned or hired by Contractor.

(c) Insurance covering physical damage to trailers and containers handled under this Agreement which are not owned or hired by Contractor, while in the care, custody and control of Contractor.

(d) All Risks Cargo insurance with limits of not less than $............ any one trailer or container, covering liability of Contractor and Railway Company for damage to contents of trailers and containers handled under this Agreement while in care, custody and control of Contractor.

(e) Bond fully indemnifying Railway Company against theft, embezzlement, or defalcation on the part of Contractor or any of Contractor's agents or employes.

(f) Money and Securities (Broad Form) insurance with limits not less than $..............

Prior to the commencement of any work under this Agreement, Contractor shall furnish to Railway Company certificates of insurance as evidence of compliance with the above requirements. All such insurances shall provide that same shall not be altered or cancelled without at least .... days prior notice to Railway Company at ....(address)...........

It is understood and agreed by Contractor that the furnishing by it of the above insurances and the acceptance of same by Railway Company is not intended to and shall not limit, affect or modify the obligations of Contractor under any provision of this Agreement.

7. Independent Contractor

The Contractor shall employ and direct all persons performing any service by Contractor hereunder, and such persons shall be and remain the sole employes of and subject to the control and direction of the Contractor and not the employes of and subject to the direction and control of the Railway Company, it being the intention of the parties hereto that the Contracor shall be and remain an independent contractor and that nothing herein contained shall be construed as inconsistent with that status.

8. Laws and Permits

In the performance of the work hereunder, the Contractor shall comply with all applicable Federal and state enactments with reference to Employers' Liability, Workmen's Compensation, and Workmen's Insurance (and when requested by the Railway Company, shall furnish proof of such compliance), and shall indemnify and hold harmless the Railway Company from and against any and all loss, liability, damages, claims, demands, costs, and expenses, of whatsoever nature, due to the existence of such enactments or resulting from any claim of subrogation provided in such enactments or otherwise. The Contractor shall also, at all times, comply strictly with all other laws, rules, regulations and ordinance—state, Federal, or municipal—applicable to operations and services to be performed by the Contractor hereunder; and the Contractor expressly agrees to indemnify and hold harmless the Railway Company from all liability for any failure or default on the part of the Contractor in this behalf.

9. Term

This contract shall take effect as of ...., 19 ...., and shall remain in effect thereafter until terminated by either party giving not less than .... written notice to the other party, provided that the Railway Company may terminate this agreement at any time immediately upon .... written notice to the Contractor by reason of any legislation, order, or rule of any public authority.

Such termination shall not be construed as relieving the other party hereto of any obligation or liability incurred prior to such termination

10. Waiver

A waiver of a breach of any of the terms or conditions hereof shall be limited to the act or acts constituting such breach and shall not be construed as being a continuing or permanent waiver of any such terms or conditions, all of which shall be and remain in full force and effect as to any future acts or happenings, notwithstanding any such waiver.

11. Assignment

This agreement, and all of the rights and obligations herein contained shall inure to the benefit of, and be binding upon the successors and assigns of the parties hereto, but no assignment by the Contractor shall be made without the written consent of the Railway Company having been first obtained.

IN WITNESS WHEREOF, the parties hereto have caused this agreement to be executed on the day and year first hereinabove written.

Witness: By........................(Railway Company)

.... By........................

Witness: ....(Contractor)

.... By........................

Report on Assignment 4

Form of Blanket Agreement Covering Utility Crossings

E. M. HASTINGS, JR. (chairman, subcommittee), J. J. BAFFA, W. F. BURT, J. K. CHRISTENSEN, R. F. CORRELL, A. P. FISH, E. A. GRAHAM, R. C. HECKEL, R. W. HUMPHREYS, F. M. JONES, R. M. MASON, J. W. RACH, J. W. WALLENIUS.

Your committee recommends that the following agreement form be accepted as Manual material, and be printed in Chapter 20, Part 5, of the Manual.

FORM OF BLANKET AGREEMENT COVERING UTILITY CROSSINGS

THIS AGREEMENT, made this .... day of ...., 19 ....,
by and between ....
a corporation duly organized and operating under the laws of ...., hereinafter called the Railway Company, and ....
hereinafter called the Utility Company.

WITNESSETH:

WHEREAS, the Utility Company has heretofore constructed, and now maintains and operates, lines of wires, cables and fixtures, over, under or across the right-of-way, tracks, property and facilities of the Railway Company at various points on its system, and

WHEREAS, the Utility Company desires in the future, from time to time, to construct, operate and maintain additional lines of wires and cables, over the right-of-way, tracks, property and facilities of the Railway Company, and

WHEREAS, the parties hereto mutually agree, for the protection of the property and rights of both, to make and enter into an agreement with respect to all such crossings as have heretofore been made, and may hereafter be made by the Utility Company;

NOW THEREFORE, in consideration of the mutual covenants and conditions herein stipulated, to be kept by the parties hereto, it is agreed as follows:

1. Permit

The Railway Company licenses and permits the Utility Company, at its sole risk, cost and expense, to continue to maintain and operate the said lines, over, under or across the right-of-way, tracks, property and facilities of the Railway Company, that existed as of the .... day of ...., 19 ...., a schedule of all such crossings, by locations, being hereto attached and marked for identification "Exhibit A," and made a part hereof, and to construct, operate and maintain additional crossings at such points as may be mutually agreed upon in the future, upon the terms and conditions of this agreement.

2. New Construction

Whenever the Utility Company desires to construct crossings at new locations, the Utility Company shall make application in writing and submit drawings, showing the plan, elevation and method of the proposed new construction to the Chief Engineer, (or other appropriate officer of the Railway Company having jurisdiction) and the new construction shall be subject to the consent and approval of the Railway Company. Such drawings shall be submitted in .... (show number of copies) and shall show the exact location of the new construction. The drawings, so approved and identified by the Railway Company and the Utility Company covering all new construction erected after ...., 19 ...., shall constitute "Exhibit B" and shall be attached to and made a part of this agreement, just the same as if listed herein.

3. Notice

The Utility Company shall notify the Railway Company at least .... in advance of commencement of any work upon said right-of-way in connection with construction, maintenance, repair or removal of the crossing facilities. In case of emergecy requiring immediate action the parties hereto shall cooperate to avoid any unnecessary delay in the performance of such work.

4. Payment

The Utility Company will pay to the Railway Company for the privilege herein granted, a fee of $................ for each and every crossing to be established over the right-of-way, tracks, property and facilities of Railway Company.

5. Relocation

The Utility Company will, at any time, and from time to time, hereinafter, as may be necessary, at its sole cost and expense, change the location or construction of its crossings to permit any changes in the grade or location of the track or tracks, telegraph or telephone lines or wires, or any other lines or structures of the Railway Company as in the opinion of the Chief Engineer are necessary, within .... days after written request from said Chief Engineer so that said crossings will at all times comply with the terms and conditions of this agreement.

6. Specifications

The Utility Company shall at its sole cost and expense construct, reconstruct and maintain its lines over, under or across the right-of-way, tracks, property and facilities of the Railway Company, in accordance with the latest issue of the National Electrical Safety Code, or any revision thereof, the provisions of applicable statutes and orders, rules or regulations of any competent public authority, and in such a manner as not to interfere in any way with the business or facilities of the Railway Company.

In the event the applicable standards are hereafter revised, then any changes in or addition to said facilities, shall conform with the applicable revised standards which are in effect at the time such changes or additions are made.

7. Alteration and Maintenance

The Utility Company will bear the cost, subject to the provisions of Sec. 5 hereof, of any changes or alterations which the construction, reconstruction, maintenance or removal of said crossing may necessitate in the relocation or rearrangement of the facilities of the Railway Company. The Railway Company may at its election have a representative to supervise such portion of the Utility Company's construction or reconstruction as may be performed within the Railway Company's right-of-way. Any work to support any tracks or structures of the Railway Company, or any flagman or other personnel deemed necessary by the Railway Company for the purpose of protecting or safeguarding its property, traffic, patrons or employees, while such crossing is being constructed, reconstructed, maintained or removed, shall be furnished by the Railway Company at the expense of the Utility Company.

8. Indemnification

The Utility Company will indemnify and save harmless the Railway Company from and against any and all loss or damage to property of, or property in the care or custody of the Railway Company and from and against all loss, damages, costs, charges, or expenses on account of any injuries accruing to the Utility Company or its employees, and from and against all claims, demands, suits, judgments and sums of money accruing to the Utility Company or to any other party, against the Railway Company, for loss of life or injury or damage to persons or property, which may be caused by cluttering or sagging of wires or falling of poles or otherwise, either to person or estate, and arising by reason of, or in connection with the construction, reconstruction, maintenance or removal by the Utility Company, or presence of any of its wires, cables, poles, conduits or other appurtenances upon, over or under the premises of the Railway Company: PROVIDED, however, that nothing herein shall be construed as indemnifying the Railway Company against its own negligence or the negligence of its own employees when such negligence is the cause of such loss, damage, injury or death; and PROVIDED, further, that the Railway Company shall promptly notify the Utility Company of any claim, demand, suit, or other action brought against it or them and wherein the Utility Company may be liable as agreed to herein, then the Utility Company shall have the right to settle or defend the same at its election.

9. Insurance

The Utility Company shall carry, at all times while this agreement is in effect, Public Liability Insurance covering bodily injury or death in limits of not less than $............. for the injury or death of each person, and $............. for each accident; and Property Damage Liability Insurance in limits of not less than $.............. for each accident, and a total aggregate limit of $.............. for the annual policy period.

10. Termination

The Utility Company has the right to continue to erect crossings pursuant to the terms of this agreement, except that upon .... days written notice by either party of its intention to terminate the same, and stating the date of such termination, no additional crossings shall be made by the Utility Company under this agreement. It is understood, however, that the crossings which shall have been constructed prior to such termination, shall thereafter be maintained and operated in accordance with, and continue to be subject to, all the conditions and stipulations contained in this agreement.

11. Taxes

The Utility Company shall promptly pay and discharge all taxes, assessments and other governmental or municipal charges upon its facilities located upon, over, under or across the right-of-way of the Railway Company.

12. Existing Agreements

It is understood and agreed by and between the parties hereto, that for the further consideration of $................, this agreement cancels and supersedes, as of the date hereof, all existing agreements covering crossings, listed in Exhibit A, said crossings to be subject to and covered by the provisions of this agreement.

13. Successors

This agreement shall inure to the benefit of and be binding upon the respective successors and assigns of the parties hereto, provided that the Utility Company shall not transfer, assign or allow the use of the permit herein granted by any person or corporation without the consent and agreement, in writing, of the Railway Company being first obtained.

14. Removal

If at any time the Utility Company shall discontinue the use of a crossing covered hereunder, it shall so notify the Railway Company, and the Utility Company shall, at its own cost and expense, promptly remove the same from over or under the right-of-way, tracks, property and facilities, and restore the Railway Company's premises to the same condition they were in prior to the construction of such crossing.

15. Intent

The intent of this agreement is to cover crossings of Railway Company property only, and is not intended to permit occupation, either longitudinal or parallel, of Railway Company property by future crossings.

In Witness Whereof, the parties hereto have caused this agreement to be executed the day and year first above written.

Witness ....Railway Company
By ....

Witness ....Utility Company
By ....

American Railway Engineering Association—Bulletin

Bulletin 611 January 1968
Proceedings Vol. 69*

REPORTS OF COMMITTEES

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The reports in this issue of the Bulletin will be presented to the 1968 Annual Convention of the Association at the Palmer House, Chicago, March 19–21, 1968. Comments and discussion with respect to any of the reports are solicited, and should be addressed to the chairman of the committee involved, in writing, in advance of the Meeting, or from the floor during the Meeting.

* The contents of this Bulletin and the other Bulletins of the Association from Bulletin 608, September–October 1967, to and including Bulletin 614, June–July 1968 (except Bulletin 613, March 1968), will constitute the Annual Proceedings of the Association, Vol. 69.

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Report of Committee 6—Buildings

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(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 6.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   It is proposed that the present, rather extensive detailed construction specification be replaced with two new sections in the manual. One section will be a bibliography or reference section of construction specifications which can be easily kept current. The second section will consist of complete design criteria for specific railway building types. A progress report covering format, schedule, and methods of implementation is being developed.

2. Buildings, platforms, ramps, paving, lighting and other facilities for piggyback terminals.
   Because of the rapid growth and expansion in this field, new concepts are being developed constantly. The committee is collaborating with the National Railroad Piggyback Association and is developing an interim report. The scope of this assignment is such that it should be kept open for supplemental reports to be filed covering new developments.

3. Ceiling systems for air supply and sound control.
   Final report, presented as information .... page 386

4. Design criteria for railway office planning.
   This assignment is concerned with developing the functional and physical requirements for modern offices, including office machinery and furniture. Report for information is being prepared.
5. Design criteria for railway train and engine crew facilities.
   An attempt is being made on this assignment to develop an acceptable standard or range of standards to be used as a yardstick in designing crew facilities. Because of the variables and complexities of local and state regulations, considerable research is required. Report for information is being prepared.
6. Computer uses for railway building design, collaborating as necessary or desirable with the Special Committee on Systems Engineering.
   The committee considers this to be an extremely timely and complex assignment. Interim reports will be filed periodically for information.

THE COMMITTEE ON BUILDINGS,
W. C. HUMPHREYS, *Chairman.*

AREA Bulletin 611, January 1968.

Report on Assignment 3

Ceiling Systems for Air Supply and Sound Control

A. W. CHARVAT (chairman, subcommittee), J. H. ADAMS, JR., F. R. BARTLETT, E. P. BOHN, A. R. GUALTIERI, D. F. LOGAN, W. K. MCFARLING.

Your committee submits the following report as information.

As a result of the use of more and more mechanical equipment and business machines, there has been an increasing awareness of the importance of noise control in commercial and office spaces. It has become almost standard practice to use materials in these areas that will eliminate, as much as possible, the reflection as well as the transmission of such sounds.

Reduction of sound reflection can be achieved to a great extent through the lowering of ceilings in the areas in question and the use of sound-absorbing material in the construction of these ceilings. The direct result of these criteria was the development of the suspended acoustical ceiling with its grid system and lay-in tiles.

Recently, manufacturers of suspended acoustical ceiling systems, after much study and research, have developed tile units that will not only reduce sound reflection but will also control the thermal and ventilating requirements in the space below it. The concept, based on the principle of air flow due to a difference in pressure between two spaces, resulted in a new air distribution system that eliminates the need for point source diffusers or other noticeable openings in the ceilings, required in a conventional system, as well as the accompanying drafts resulting therefrom.

The new air distribution system, which heats, cools and ventilates as required, employs acoustical tile containing a number of perforations or slotted openings through which the conditioned air is forced into the space below it. In this system the air is conditioned in and fed from conventional primary equipment into a main duct and from there through stub ducts into a plenum, formed by the enclosing walls, the floor above and the acoustical tile ceiling, thence through the perforations or slots in the tile to the space being conditioned. To complete the cycle, the air is returned to the primary equipment or exhausted as required, in the conventional manner, through return grilles or diffusers and ductwork. Since the plenum must be pressurized to cause the air to flow into the space below, it is imperative that there are no leaks or negative pressures in the plenum chamber.

Conditions in any one room will vary, and to satisfy the physiological requirement of the occupant of the room, the air motion should be varied accordingly. Outside walls, windows, doors, heat-producing machines and isolated work areas all require some secondary control of air motion for working comfort. This secondary control has been achieved by one manufacturer from the pattern of slotted and unslotted acoustical panels used and from the adjustable dampers on the back of the slotted panels. Another manufacturer provides, by varying the size and number of perforations, tiles that offer two different air-flow resistances, and by varying the proportions of one to the other the distribution can be varied accordingly.

A comparison indicates that the integrated acoustical-ventilating ceiling system can claim several advantages over a conventional air distribution system, including simplified construction, draft-free air circulation, lower maintenance and an improved esthetic environment. The use of the space above the ceiling as a plenum chamber reduces and simplifies the amount and construction of the ductwork required, which in turn frequently permits a lesser plenum depth and in many cases allows a reduction in the overall height of the building. Drafts are virtually eliminated as the air in-flow, not being limited to individual outlets, can be spread over the entire ceiling, thus providing a uniform air distribution at much lower velocities. The uniform air distribution as well as the downward movement keeps the dust and dirt from settling on the ceiling, minimizing streaking and soiling of same, and reducing the maintenance accordingly. In addition, the ceiling presents an undisturbed appearance as the diffusers or other openings required in a conventional system are supplanted by the slots or perforations that are integrated into the surface design of the panels, making them virtually invisible.

Report of Committee 7—Wood Bridges and Trestles

°**D. V. Sartore,** *Chairman*
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L. E. Titlow
S. J. Zajchowski
Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 7.

To the American Railway Engineering Associaiton:

Your committee reports on the following subjects:

1. Revision of Manual.
   A general review of Chapter 7 of the Manual is now in progress.
2. Grading rules and classification of lumber for railway uses; specifications for structural timber, collaborating with other organizations interested.
   No report.
3. Specifications for design of wood bridges and trestles.
   Progress has been made on a proposed revision of the specifications pertaining to horizontal shear. A full report will be made next year.
4. Methods of fireproofing wood bridges and trestles, including fire-retardant paints.
   No report.
5. Design of structural glued laminated wood bridges and trestles.
   Recommendations for revision of Manual have been published in the Manual Recommendation Supplement to Bulletin 610, December 1967.
6. Evaluation of cost of various sizes of bridge timbers.
   Questionnaires have been distributed to a number of railroads requesting information regarding size and species of the various members comprising timber trestles on these railroads. This information has

been received and is being compiled into a form which includes specifications necessary for purchase, and will then be distributed to the timber-producing industry to obtain costs. This information will then be used to determine the cost evaluations contemplated by this assignment.

7. Repeated loading of timber structures.
Progress report, submitted as information .... page 391

8. Protection of pile cut-offs; protection of piling against marine organisms by means other than by preservatives.
Final report, submitted as information .... page 392

9. Study of in-place preservative treatment of timber trestles.
Progress report, submitted as information .... page 400

10. Non-destructive testing of wood.
Progress report, submitted as information .... page 401

THE COMMITTEE ON WOOD BRIDGES AND TRESTLES,
D. V. SARTORE, *Chairman*.

AREA Bulletin 611, January 1968.

Herbert M. Church
1881-1966

Herbert M. Church, retired general supervisor—bridges and buildings of the Chesapeake & Ohio Railway, died on October 12, 1966.

He was born on November 6, 1881, and graduated from Ohio Northern University in 1901. From 1901 to 1919 he held various engineering positions with the Baltimore & Ohio Railroad. After three years in construction and municipal engineering he returned to railroad work as assistant division engineer on the C&O. He was promoted to division engineer in 1925 and to general supervisor—bridges and buildings, in 1929, which position he held until his retirement in 1947.

He first joined the AREA in 1908 and rejoined in 1925 after his return to railroad work. He was a member of Committee 7 from 1931 to 1950, being chairman from 1938 to 1940. He was elected Member Emeritus in 1953. He was a member of Committee 6 from 1937 to 1950 and was elected Member Emeritus in 1954. He also served on Committee 13 from 1911 to 1914, Committee 5 from 1914 to 1918, Committee 22 from 1927 to 1930, Committee 9 from 1934 to 1936 and Committees 26 and 28 from 1938 to 1941.

Mr. Church was a member of the Baptist Church, the Ancient Free and Accepted Masons of Maryland, the American Society of Civil Engineers, the American Wood Preservers Association, and the American Railway Bridge and Building Association, the latter of which he was a past president.

Mr. Church will be remembered by his AREA associates, especially those on the numerous subcommittees on which he served, as a diligent worker who inspired others to extra effort.

Report on Assignment 7

Repeated Loading of Timber Structures

C. V. Lund (chairman, subcommittee), R. E. Anderson, W. L. Anderson, B. Bohannan, J. Budzileni, D. J. Engle, W. A. Genereux, F. J. Hanrahan, J. M. Helm, J. F. Holmberg, L. C. Jones, L. R. Kubacki, W. H. Martin, T. K. May, W. A. Oliver, J. A. Peterson, F. E. Schneider, N. E. Smith, I. W. Thomas, L. E. Titlow, S. J. Zajchowski.

Your committee presents as information the following synopsis of Report No. ER—76 of the AAR Engineering Research Division titled "Laboratory Investigation to Determine Static and Repeated-Load Strength of Full-Size Southern Pine Solid-Sawn Stringers."

This is the fourth report on tests conducted at the Research Center of full-size bridge stringers in repeated loading. Previous reports on glued laminated fir and pine stringers appear in Vol. 64 and Vol. 66 of AREA Proceedings, and a report on solid-sawn Douglas fir appears in Vol. 68. As in previous tests, the current series is directed in particular to the determination of resistance to horizontal shearing stresses for variable load position with respect to the end support. Correlary tests on sections cut from the stringers were conducted at the Forest Products Laboratory, U. S. Department of Agriculture, Madison, Wis.

In the present series, 24 solid-sawn southern pine stringers were tested in static and repeated loading to determine the horizontal shear strength at 2,000,000 cycles of stress for each of three different load positions. The stringers were 8 in. by 15¾ in. in cross section, 14 ft long, obtained from the regular stocks of one of our larger railroads, purchased to conform to Dense Structural 72 grade of the Southern Pine Inspection Bureau grading rules (1963, Par. 253), and treated to conform to the railroad's specifications for 70–30 creosote-coal tar preservative using the Lowry Process, with 16 lb per cu ft retention specified.

The stringers were tested statically and in repeated loading for each load position, by applying two equal loads spaced 4 ft 8 in apart on a span length of 12 ft 10 in. To determine the effect of load position, the first load was placed at either 1½, 2¼, or 3 times the depth of the stringers from the near support. Repeated loading at various stress levels was carried to 2,000,000 cycles or failure, whichever occurred first. The complete results of the investigation appear in the published report, including data on physical properties furnished by the Forest Products Laboratory.

In the static tests two stringers failed in tension and one in compression. In the repeated-load tests four stringers failed in shear, five in compression and one in bearing. Eleven stringers did not fail in the repeated-load tests.

Test results produce an estimated horizontal shear strength at 2,000,000 cycles of 245 psi with the first load placed at 1½ times the depth of the stringer from the support (1½*d*), 240 psi with the first load at 2¼*d*, and 215 psi with the first load at 3*d*. AREA specifications currently allow 125 psi design stress for this grade of southern pine, based however on long-time duration of static loading. The critical position for shear appears to be 3*d*, although the difference in value for the three load positions is less pronounced than in other series of tests reported.

Few stringers showed an increase in deflection during test, and such increases as were measured were slight. Neither changes in deflection nor in strain-gage readings during cycling gave apparent indication of imminent failure.

In supplementary static tests of the 11 stringers which did not fail in repeated loading, all but three developed shear strengths at time of failure in excess of that of the single static control specimen tested; most of the failures in these supplementary tests, however, were in tension.

Correlary tests conducted at the Forest Products Laboratory developed no apparent correlation between specific gravity, percent summerwood, or ring count, and shear strengths. Average specific gravity of all stringers, corrected to oven-dry weight, was determined to be 0.51, which is about average for this species. Percent summerwood varied from 21 to 56, and annular ring count varied from approximately 4 to 18 rings per inch; in these respects, 12 of the specimens failed to meet the grading rule requirements for dense structural grade, as purchased by the railroad.

Grading of the beams was undertaken by the Southern Pine Inspection Bureau. Its inspector reported that 12 of the 24 stringers failed to meet specifications when they were treated.

Report on Assignment 8

Protection of Pile Cut-Offs; Protection of Piling Against Marine Organisms by Means Other Than by Preservatives

W. A. Thompson, Jr. (chairman, subcommittee), E. L. Bangs, K. L. DeBlois, George Gabel, Jr., W. A. Genereux, S. L. Goldberg, E. S. Gordon, J. A. Gustafson, J. A. Hawley, J. F. Holmberg, R. H. Hunsinger, J. E. Hutto, L. C. Jones, B. J. King, R. E. Kuehner, A. L. Leach, D. H. McKibben, C. H. Newlin, J. W. Storer, L E. Titlow, D. L. Walker.

PART 1—PROTECTION OF PILE CUT-OFFS

Epoxy Resin Pile Top Protection

The AAR Research Center conducted a series of laboratory tests to determine the effectiveness of several epoxy resin systems when used to protect pile tops after cut-off. The test set up consisted of a 13-in round pile stub, 1 ft 2 in long, and a short length of 14-in by 14-in cap connected by a ¾-in drift bolt. The pile stub was set in a shallow pan of water. The entire assembly was mounted on a test machine so that repetitive loads could be applied equivalent to design bearing pressure.

The first epoxy system tried was the General Purpose Adhesive, 991–67 (see Vol. 62, p. 535). This system was able to carry the repetitive loads and bonded well to the pile top, but radial cracks developed in the epoxy due to changes in moisture content in the pile. This epoxy system was then flexibilized by increasing the converter portion, but this reduced the compressive strength of the system and it failed in bearing.

To eliminate the radial cracking and still provide a hard capping material, a combination of the 991–67 adhesive and glass fabric was tried. The adhesive was spread on the pile top in the usual manner. A sheet of glass fabric was placed over this and lapped down the sides of the pile a few inches and tacked in place. Another layer of adhesive was then placed on top of the fabric and the timber cap installed. No radial cracks were observed.

In all these tests a sheet of polyethylene was placed between the timber cap and the epoxy to prevent bond at this surface. Also, the drift bolt was driven into the pile while the epoxy was liquid.

Some other epoxy systems were tried, but the general purpose adhesive with the glass fabric appeared to be the most satisfactory for this application.

PART 2—PROTECTION OF PILING AGAINST MARINE ORGANISMS BY MEANS OTHER THAN BY PRESERVATIVES

Your committee presents the following information to familiarize members with the problems encountered with marine borers and to present known methods of dealing with these problems.

Marine borers are classified into two general groups, Mollusca and Crustacea.

The Mollusca attack at the surface of wood and destroy internally. The principal types of marine borers in this group are Teredo, Bankia, and Pholad.

The Pholad burrows into wood for protection by the rasping action of its shell, and as it grows it enlarges its hole accordingly. It rarely penetrates deeper than 2½ in, and is usually less destructive than other marine borers. However, in some areas it can cause considerable weakening of timbers. Pholads are usually found in tropic and semi-tropic waters.

From an economic standpoint the most important types of mollusean borers are the Teredo and Bankia. These burrow into wood for food, as well as protection, and are generally found throughout the entire Atlantic, Gulf and Pacific Coast areas. Beginning as eggs, these borers quickly develop into free-swimming larvae and must soon find wood or die. Attaching to the surface of wood, they burrow a tiny hole, which is the only indication of their presence. Once inside the wood, they usually follow the grain of the wood, and their direction is not changed except to avoid objects such as bolts or tunnels of other borers. As it grows, the Teredo continually lengthens and enlarges its hole by the rasping action of its clam-like head, while at the same time it coats its burrow with a thin calcium deposit. Unlike other Mollusca, which close their shells for protection, the Teredo has a long, worm-like body with only the head end contained in the shell (see Fig. 1) and is doomed to spend the rest of its life in a self-created prison. While the Teredo may grow as much as 2 in. a month in cold water and as much as 8 in. a month in warm water and to a maximum length of 6 in to 6 ft, depending on the species and location, it always depends on its tiny entrance hole for life support. From this hole it receives fresh water and particles of food and deposits waste material through small transparent tubes or siphons about an inch in length, and when it is disturbed it can withdraw its siphon and seal its hole so effectively that it can live for several weeks even if the wood containing the borer is removed from the water. Because of its

Official Photograph, U. S. Navy

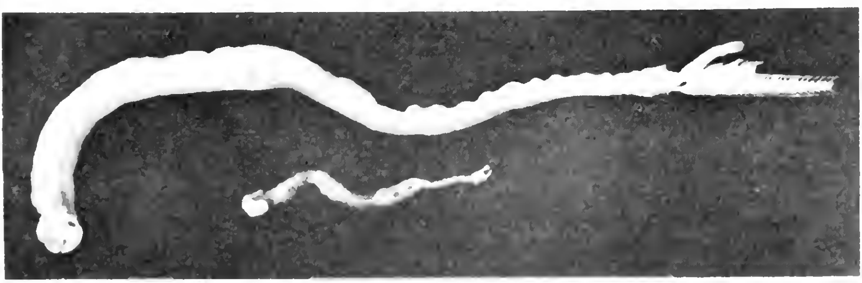


Fig. 1

Official Photograph, U. S. Navy

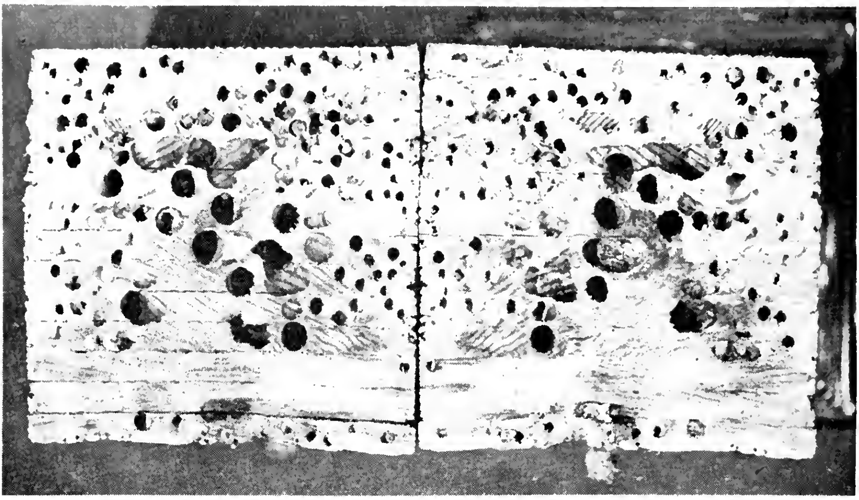


Fig. 2

rapid growth the Teredo can do tremendous internal damage to under-water timbers and in some areas can render new piling unsafe in as little as six months (see Fig. 2).

The Crustacea, like the Mollusca, have long been a source of food for man. Some of the better known forms of Crustacea are shrimp and lobster. However, the smallest of the phylum, the Limnoria, are probably the most important from an economic standpoint because of the vast amount of damage they do annually (see Fig. 3).

The Limnoria resembles a shrimp and at maturity is about 1/5 to 1/10 in long. Newly born Limnoria resemble the adult and are born capable of attacking wood. Unlike Teredo, Limnoria prefer to live in colonies just under the surface of the wood. They burrow with the grain of the wood and continually punch holes through the wood to the surface to get a fresh supply of water and life-giving oxygen. Their burrows are so close and punctures so frequent that normal wave action easily carries away the outer layer of wood, exposing the borers (see Fig. 4), which begin a new system of burrows. This process is repeated until the wood is destroyed.

Where wood has been protected at the surface, the tiny Limnoria may attack in splits or bolt holes which reach unprotected wood, and then unseen, the damage can be extensive and often complete (see Fig. 5).

Once infested with marine borers, piling can be weakened or destroyed in relatively short time, and it is necessary that a method of inspection be established to determine their presence. For many years it was thought the Limnoria, which produces the "hour glass" effect, was dangerous only in the tidal area. However, after about 1930 it was found they can damage piling all the way to the mud line. Therefore, visual inspection at low tide became ineffective, and it was determined that the best method of piling inspection was by hard-hat divers. Complete records

Official Photograph, U. S. Navy

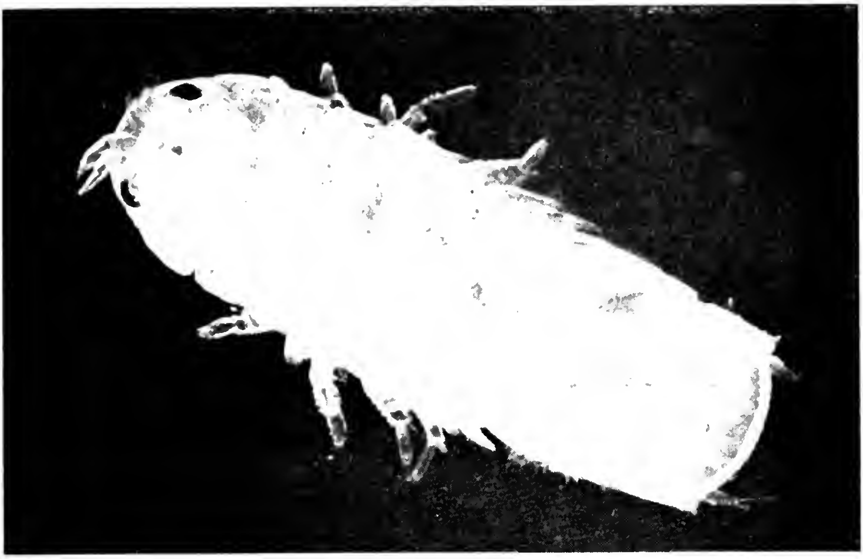


Fig. 3

Official Photograph, U. S. Navy

Fig. 4

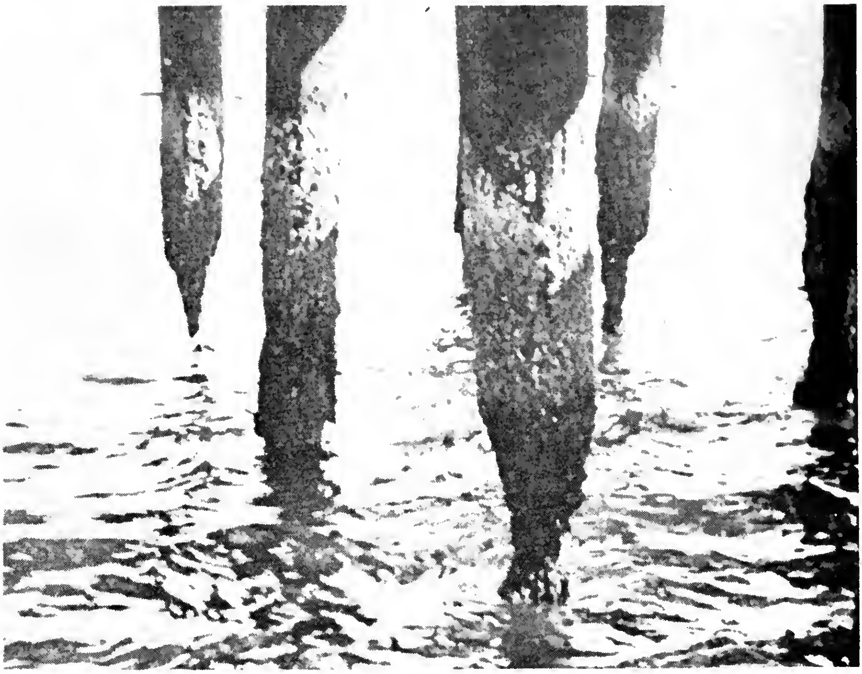


Fig. 5

should be kept as to the condition of the piling and after each periodic inspection, comparison made to determine extent of activity. If more borer activity is indicated to the extent that the structure is threatened, it may be advisable to utilize some sort of in-place pile protection.

Numerous methods have been developed for protection of in-place timbers from marine borers. However, only three of these methods meet requirements to justify their use, these requirements being cost and results. All three methods employ the same principle of stagnating the water, thereby shutting off the supply of oxygen, and all of these methods appear to work equally well in this respect. They are as follows:

Concrete Jackets

This method employs the use of a thin shell of concrete, usually 2½ to 4 in thick, which is poured around the piling between the mud line and the high-water mark, or, if the depth is too great, between the high- and low-water marks. Concrete jackets are effective in preventing damage due to marine borers. However, some disadvantages are difficulty in forming and pouring concrete under water, additional dead load on piling, and inability to remove jacket to inspect piling or timbers. Average cost of piling protection by concrete jackets is $11 to $20 depending on local conditions.

Official Photograph, U. S. Navy

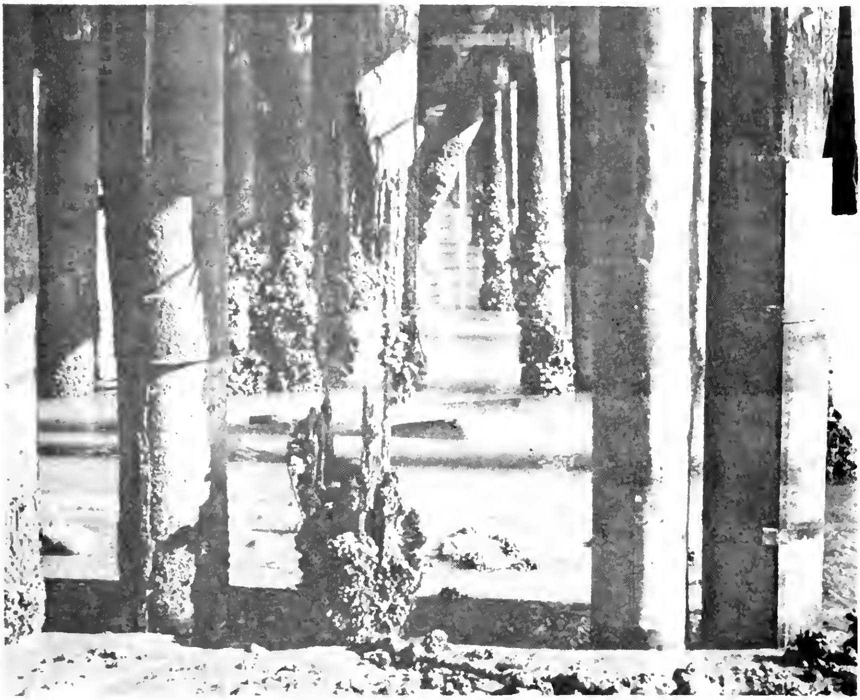


Fig. 6

Copper-Nickel Sheeting

Metal sheeting approximately 20 mils (0.02 in) thick, comprising 90 percent copper and 10 percent nickel, has been found to be an effective barrier against marine borers when secured tightly to timber piling or formed loosely around the piling and back-filled with sand (see Fig. 6). This formulation of metals has been found to resist corrosion due to salt water, and the copper produces toxic poison deadly to marine borers. Some disadvantages are difficulty in applying and susceptibility to mechanical damage. Also, it is difficult to remove for visual inspection of the piling. Average cost of piling protection by copper-nickel sheeting is $8 to $10 per foot.

Polyvinyl Chloride Sheeting

Polyvinyl chloride sheeting varying in thickness from 20 to 30 mils is secured around piling by the use of patented devices to secure a nearly airtight seal, eliminating marine borers by shutting off the oxygen supply (see Fig. 7). This sheeting can be made in any size or length for varying conditions of borer activity and is easily secured to the piling. Results are usually good, and the sheeting can easily be removed for visual inspection and replaced. This type of wrapping is susceptible

Fig. 7

to mechanical damage but can be patched. High-impact, rigid, polyvinyl chloride sheeting is now available which is considerably stronger (see Fig. 8). Average cost of piling protection by this means is $5 to $6 per foot.

This is a final report, submitted as information, with the recommendation that this assignment be discontinued until there are further developments.

Official Photograph, U. S. Navy

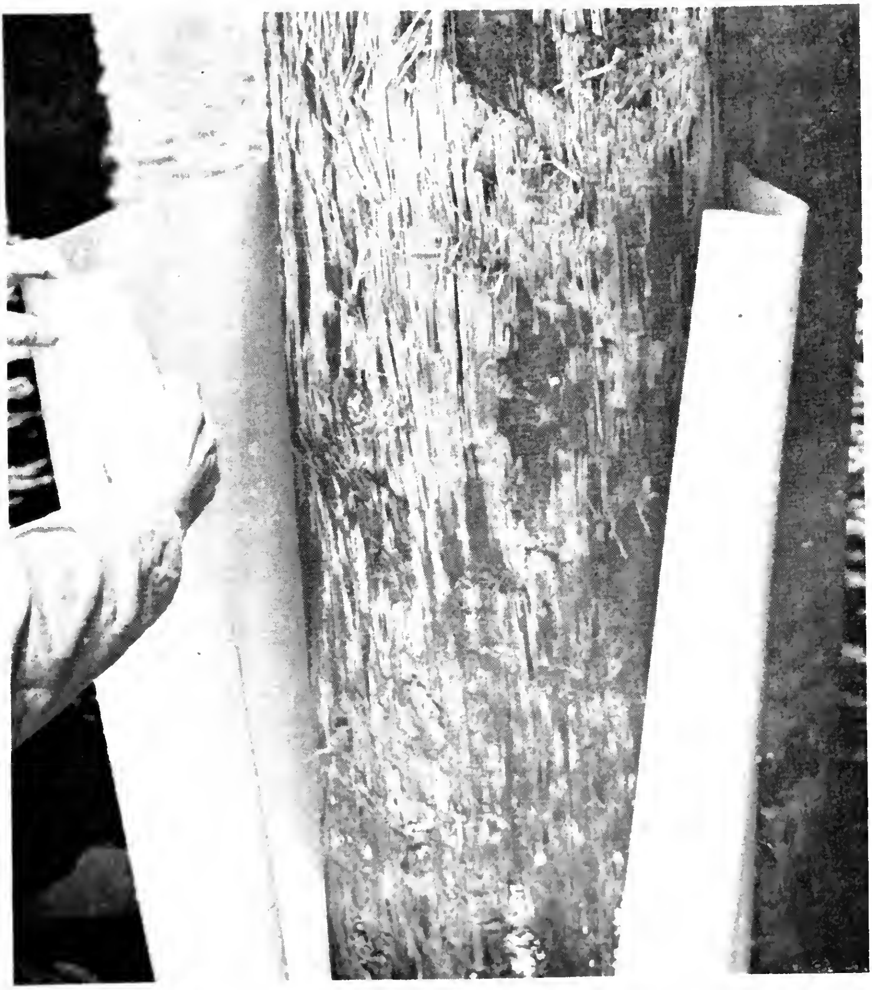


Fig. 8

Report on Assignment 9

Study of In-Place Preservative Treatment of Timber Trestles

D. L. Walker (chairman, subcommittee), E. L. Bangs, T. P. Burgess, J. W. Chambers, B. E. Daniels, K. L. DeBlois, D. J. Engle, E. S. Gordon, J. E. Hutto, L. C. Jones, B. J. King, A. L. Leach, J. W. N. Mays, D. H. McKibben, C. H. Newlin, J. J. Ridgeway, F. E. Schneider, G. N. Sells, J. W. Storer, I. W. Thomas, W. A. Thompson, Jr., L. E. Titlow.

Your committee presents this progress report as information.

The AAR Research Center has received several specimens of trestle piling which had received an in-place treatment of pentachlorophenol. Some of these specimens were treated recently and others were treated as long ago as 11 years. Samples of these piles are being analyzed in the laboratory to determine the retention and penetration of the preservative.

Test samples for analysis are obtained as follows:

1. Pile is cut into short lengths to locate the decay zone.
2. The piece having the greatest decay is then trimmed to a smooth surface and a 2-in-thick slice cut off.
3. On this slice, four 1-in-wide strips are cut out, radiating from the void area.
4. Slices ¼ in thick are cut from each strip, placed in a plastic bag and marked to show location along the pile and at the cross section.
5. Each 1-in by 2-in by ¼-in specimen is then powdered in a mill for the chemical analysis.

The method of analysis for determination of pentachlorophenol is the American Wood Preservers Association Standard AWPA A5-64, the Copper-Pyridine Method.

This method of analysis is based on the formulation of a copper-pyridine-chlorophenol complex that is insoluble in water, but readily soluble in chloroform to which it imparts a brownish-yellow color. Wood samples are analyzed by first extracting the penta with a solvent, then the formulation of the complex, which is analyzed by an ultraviolet absorption method using a photo-electric colorimeter with a 450 millimicron light filter, matched absorption cells, and separatory funnels.

A report on these analyses is in preparation.

Report on Assignment 10

Non-Destructive Testing of Wood

F. E. SCHNEIDER (chairman, subcommittee), W. L. ANDERSON, E. L. BANGS, J. BUDZILENI, B. E. DANIELS, GEO. GABEL, JR., R. W. GUNTHER, F. J. HANRAHAN, J. R. HAWLEY, J. E. HUTTO, B. J. KING, L. R. KUBACKI, R. E. KUEHNER, C. V. LUND, W. H. MARTIN, J. W. N. MAYS, C. H. NEWLIN, J. J. RIDGEWAY, G. N. SELLS, J. W. STORER, I. W. THOMAS, W. A. THOMPSON, JR.

The following progress report is submitted as information:

Present methods of inspection to locate decay in large structural timbers are damaging to the timber because of the probing, sounding or boring of holes that is necessary. Committee 7 thus initiated the assignment, "Non-destructive Testing of Wood."

Two sonic pole-testing devices have recently been demonstrated at the AAR Laboratory for measuring and recording known decay in some old bridge timber. After the tests were made with the sonic devices and all results of internal decay recorded, specimens were cut apart to evaluate the instrument readings.

In general, both devices gave fairly good indication as to whether or not decay was present. Neither one, however, indicated the size of the internal void, but the manufacturers made no claim in this regard. Moisture in the wood or on the surface had no apparent effect on the instrument readings.

The AAR Laboratory has prepared a report on these devices, Report No. ER-75, which covers the entire demonstration and tabulates all results. An abstract of this report was published in AREA Bulletin 608, September–October 1967, beginning on page 26.

Report of Committee 8—Masonry

R. J. Brueske, *Chairman
F. A. Kempe, Jr., *Vice Chairman
***W. R. Wilson**
G. W. Cooke
***J. R. Williams**
***W. P. Hendrix**
***J. R. Iwinski**
W. F. Baker
E. L. Bangs
E. R. Blewitt
W. E. Brakensiek
H. C. Brown
M. J. Crespo
E. J. Daily
M. T. Davisson
J. W. DeValle
J. W. Dolson
B. M. Dornblatt
D. H. Dowe
F. C. Edmonds
W. J. Eney
J. A. Erskine
T. L. Fuller
W. L. Gamble
C. W. Hale
R. J. Hallawell
W. A. Hamilton, Jr.
C. W. Harman
G. P. Hayes, Jr.
H. W. Hopkins
A. K. Howe
T. R. Kealey
R. J. Klueh
R. E. Kuban
A. N. Laird (E)
L. Lange, Jr.
G. F. Leyh
E. F. Manley
L. M. Morris (E)
David Novick
B. J. Ornburn†
R. E. Pearson
J. E. Peterson
Milton Pikarsky
H. D. Reilly
E. D. Ripple
F. A. Russ, Jr.
J. H. Sawyer, Jr.
M. P. Schindler
H. H. Schmidt
Everett Scroggie
J. E. Scroggs
G. R. Shay
R. K. Shortt
L. F. Spaine
C. H. Splitstone (E)
W. J. Sponseller
S. A. Stutes
Anton Tedesko
W. C. Teng
M. F. Tigrak
G. R. Vanderpool
F. H. Vines
Earl Watson, Jr.
J. W. Weber
J. O. Whitlock
J. M. Williams
G. A. Wolf
R. J. Wright
Committee

(E) Member Emeritus.
† Died February 23, 1967.
Those whose names are shown in boldface, in addition to the chairman and vice chairman, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 8.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
Manual revisions submitted for adoption were published in the Manual Recommendation Supplement to Bulletin 610, December 1967.

2. Design of masonry structures, collaborating as necessary or desirable with Committees 1, 5, 6, 7, 15, 28, and 30.
Brief status report, submitted as informatnon .... page 405

3. Foundations and earth pressures, collaborating as necessary or desirable with Committees 1, 6, 7, 15, and 30.
Brief progress report, submitted as information .... page 405

6. Prestressed concrete for railway structures, collaborating as necessary or desirable with Committee 6.
Progress report, presented as information .... page 406

7. Quality of concrete and mortars, collaborating as necessary or desirable with Committee 6.
   Manual revisions submitted for adoption were published in the Manual Recommendation Supplement to Bulletin 610, December 1967.
8. Waterproofing for railway structures, collaborating as necessary or desirable with Committees 6, 7, and 15.
   Brief status report, submitted as information .... page 447

THE COMMITTEE ON MASONRY,
R. J. BRUESKE, *Chairman.*

AREA Bulletin 611, January 1968

Benedict J. Ornburn
1900-1967

Mr. Ornburn was born July 21, 1900, at Granville, Mo. He received his higher technical training at the University of Missouri. He first entered railroad service in June 1922 as a rodman on the Wabash Railway (now part of the Norfolk & Western Railway) at Moberly, Mo. The following year he began work for the Missouri State Highway Commission as a bridge detailer, and later as a checker of design plans. He was next employed by the Morland Refining Company as a structural engineer at Ponca City, Okla. In 1926–1927, he joined the firm of Harrington–Howard & Ash, consulting engineers, at Kansas City, Mo., as a structural engineer.

In 1929 Mr. Ornburn joined the staff of the Montana State Highway Department as a design engineer. In 1930 he became bridge engineer and in 1935, bridge design engineer. He joined the Northern Pacific Railway in April 1942 at Seattle, Wash. and advanced to assistant bridge engineer a year later. He entered the service of the Milwaukee Railroad in Chicago in August 1946 as assistant bridge engineer and was promoted to superintendent bridges and buildings the following year. On April 1, 1960, Mr. Ornburn was promoted to assistant chief engineer–structures, the position he held at the time of his death.

Mr. Ornburn became a member of the American Railway Engineering Association December 9, 1942 and served on the following committees:

Committee 29—Waterproofing, 1947–1960 incl.
Emergency Committee on Structural Problems, 1950.
Committee 15—Iron and Steel Structures, 1948–50.
Committee 8—Masonry, 1947–48 and 1965–66.

Surviving Mr. Ornburn are his wife Olive; a son, Benedict J. Ornburn, Jr., residing in Pittsford, N. Y.; a brother Harry, residing in Moberly; and two grandchildren.

Report on Assignment 2

Design of Masonry Structures

Collaborating with Committees 1, 5, 6, 7, 15, 28, and 30

F. A. Kempe (chairman, subcommittee), W. E. Brakensiek, M. J. Crespo, E. J. Daily, F. A. Russ, Jr., J. H. Sawyer, Jr., E. Scroggie, W. J. Sponseller, A. Tedesko, F. H. Vines, J. W. Weber, G. A. Wolf.

Your committee is rewriting Part 12—Concrete Poles, of Chapter 8 of the Manual, and will continue to make revisions to Part 2—Plain and Reinforced Concrete Members.

Report on Assignment 3

Foundations and Earth Pressures

Collaborating with Committees 1, 6, 7, 15, and 30

C. W. Cooke (chairman, subcommittee), M. T. Davisson, B. M. Dornblatt, D. H. Dowe, J. A. Erskine, R. J. Hallawell, T. R. Kealey, E. F. Manley, David Novick, Milton Pikarsky, M. P. Schindler, G. R. Shay, S. A. Stutes, W. C. Teng, R. J. Wright.

Your committee wishes to report progress on two of its subjects: (a) Specifications for Embedment of Poles, and (2) Specifications for Sheet Pile Retaining Walls. These two assignments should be brought to completion in the coming year. Its third subject, (c) Bibliography on the Effect of Earthquake Forces on Pier Foundations, is at present incomplete.

Report on Assignment 6

Prestressed Concrete for Railway Structures

Collaborating with Committee 6

J. R. Williams (chairman, subcommittee), W. F. Baker, J. W. DeValle, F. C. Edmonds, W. J. Eney, T. L. Fuller, W. A. Hamilton, Jr., C. W. Harman, G. F. Leyh, J. E. Peterson, E. D. Ripple, J. E. Scroggs, R. K. Shortt, L. F. Spaine, M. F. Tigrak, G. R. Vanderpool, J. O. Whitlock, W. R. Wilson.

Your committee is currently working on the design of a prestressed concrete tie for open-deck bridges.

Another important assignment of the committee is the preparation of designs of prestressed concrete box girders over a wide range of span lengths and various span depths.

Your committee offers the following design tables and explanatory text at this time as information. With editorial revisions this material will be submitted for adoption in the Manual next year.

The design tables and text were prepared by Clifford L. Freyermuth, structural engineer, Design Section, Engineering Services Department of the Portland Cement Association using their IBM 1130 Computing System. The hundreds of man-hours spent by Mr. Freyermuth on this work, together with the computer time donated by the Portland Cement Association, are gratefully acknowledged.

Your committee also wishes to express its thanks to the Southern Pacific Company for making their computer program available to the Portland Cement Association for this work.

DESIGN TABLES FOR PRECAST-PRESTRESSED BOX GIRDERS FOR RAILWAY BRIDGES

INTRODUCTION

This publication contains design tables for the precast-prestressed box girders for railway bridges shown in Fig. 1. The design live load is Cooper E 72. Two sets of tables are presented to meet two separate design criteria. In the first set, tension is permitted in the top slab; in the second set tension in the top slab is not permitted. The designs for the 3-ft 0-in and 4-ft 0-in wide single-celled boxes are suitable for spans from 26 ft to 84 ft. The designs for the three double-celled box widths are for spans from 26 ft to 50 ft. In most instances, the design tables provide data for a range of box depths for a given span. Where vertical clearance is not critical, the deeper boxes usually offer an economic advantage.

Span limits for the tables were chosen to cover most normal design requirements with conventional design parameters. However, for specific projects the engineer may wish to vary the parameters chosen or design for spans beyond those covered by the tables. For this purpose, program card decks and instructions for the computer program used to develop these design tables will be made available on request to a PCA District Office.

A flow diagram for the main computer program is presented in Fig. 2. Typical output sheets from the computer program are reproduced in Figs. 3 and 4. The program will accommodate post-tensioned designs as well as the pretensioned designs included in the tables.

(Text continued on page 411)

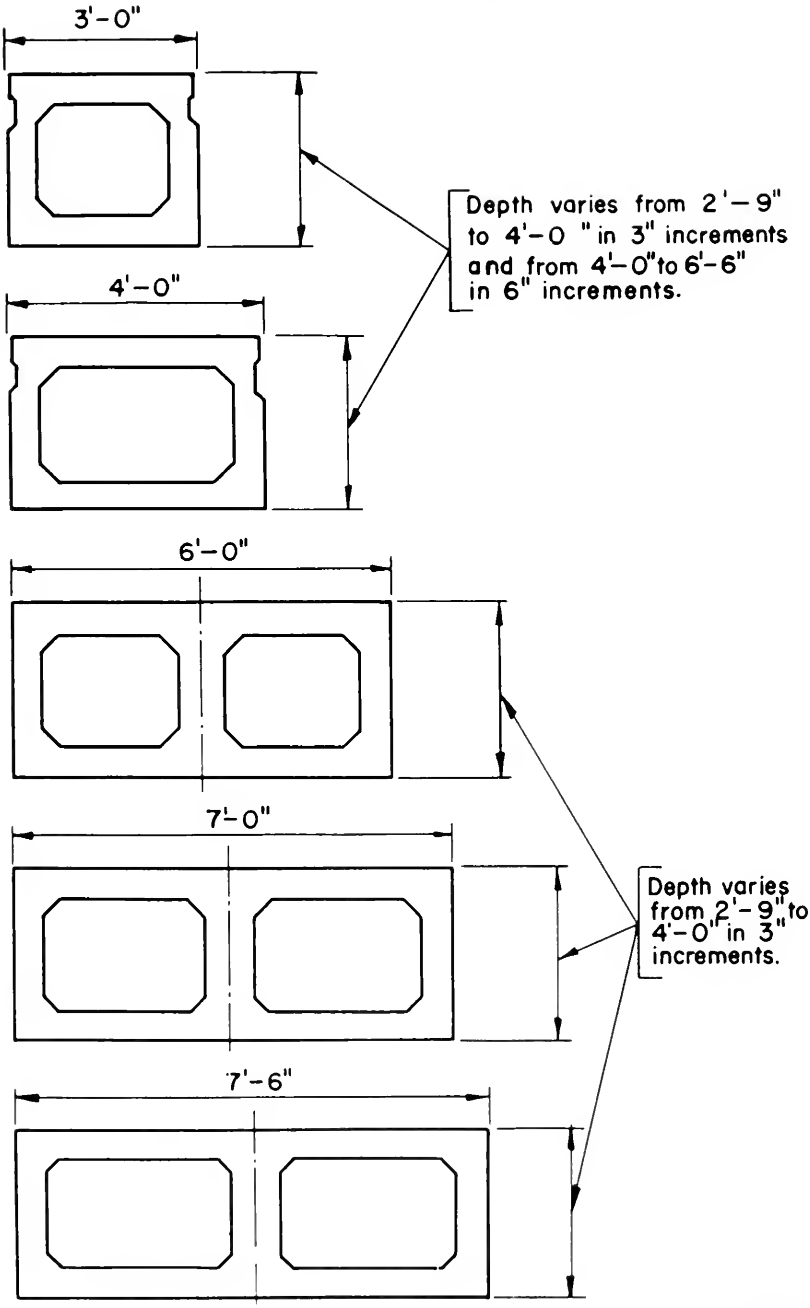

3'-0"
4'-0"
Depth varies from 2'-9" to 4'-0 " in 3" increments and from 4'-0" to 6'-6" in 6" increments.
6'-0"
7'-0"
Depth varies from 2'-9" to 4'-0" in 3" increments.
7'-6"

FIG. 1

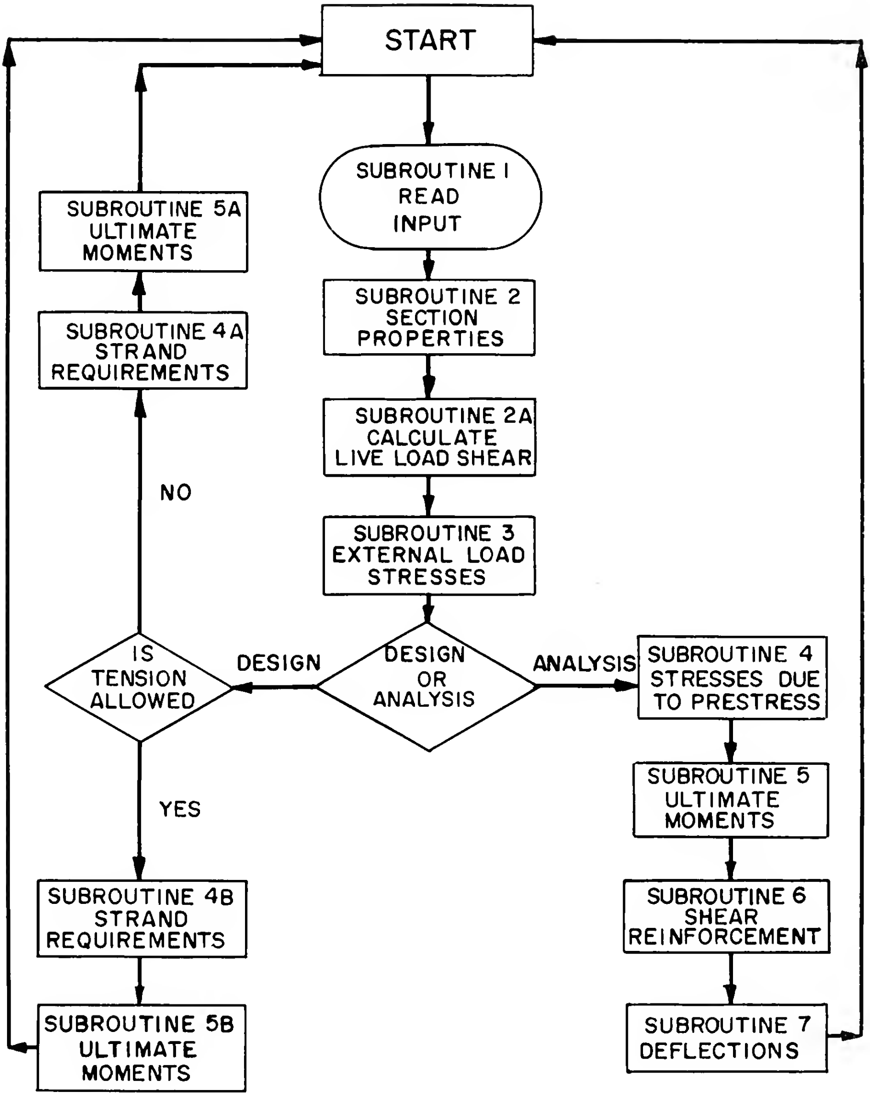


FIG. 2 FLOW DIAGRAM FOR COMPUTER PROGRAM

```
   PORTLAND CEMENT ASSOC.,              JOB NO. 65   DATE
      DESIGN SECTION                    STRUCTURE    2FT9 BOX   30FT SPAN
                                        SUBJECT
 PRESTRESSED GIRDER ANALYSIS            DATA BY    CLF   CHECKED BY


  BOX WIDTH =    4.000FT.  BOX DEPTH =   2.750FT.   TOP SLAB =   5.500IN.   BOT SLAB =   5.500IN.
  SIDE WALL =    5.000IN.  CEN. WALL =   0.000IN.     FILLET =   3.000IN.      DELTA =   0.000IN.


  SECTION PROPERTIES
  AREA =      766.00    YB =    16.500    YT =    16.500
     I =    111838.     SB =    6778.0    ST =    6778.0     Q =    4325.0
  STRESSES IN EXTREME FIBERS DUE TO EXTERNAL LOADS
  DIST          BEAM WT              SDL              LIVE LOAD              TOTAL
             TOP       BOT       TOP       BOT       TOP       BOT       TOP       BOT
 0.500 L    0.158    -0.158     0.146    -0.146     1.160    -1.160     1.465    -1.465
 0.333 L    0.141    -0.141     0.129    -0.129     1.063    -1.063     1.334    -1.334
 0.250 L    0.119    -0.119     0.109    -0.109     0.876    -0.876     1.105    -1.105
 0.000 L    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     STRANDS MINIMUM =  23.842    YM =    7.651    YE =    7.651
  DIST    INITIAL PRESTRESS        BEAM WT +          BEAM WT + SDL +      ALL LOADS +
                               INITIAL PRESTRESS     FINAL PRESTRESS     FINAL PRESTRESS
             TOP       BOT       TOP       BOT       TOP       BOT       TOP       BOT
 0.500 L    0.000     1.674     0.158     1.515     0.305     1.160     1.465    -0.000
 0.333 L    0.000     1.674     0.141     1.532     0.271     1.194     1.334     0.130
 0.250 L    0.000     1.674     0.119     1.554     0.228     1.236     1.105     0.360
 0.000 L    0.000     1.674     0.000     1.674     0.000     1.465     0.000     1.465
  ULTIMATE MOMENT REQUIRED =     1831.
  ULTIMATE MOMENT PROVIDED

     5.000      270.000       5.109      25.348       0.002       3.519     248.916
     5.000      270.000       5.312      25.348       0.003       3.672     247.999
     5.000      270.000       5.513      25.348       0.003       3.825     247.082
     5.000      270.000       5.712      25.348       0.003       3.978     246.166
  FOR FCULT = 5.000   AND,    26.   STRANDS    UMP =    1856.
     5.500      270.000       4.680      25.348       0.002       3.519     250.832
     5.500      270.000       4.868      25.348       0.003       3.672     249.999
     5.500      270.000       5.054      25.348       0.003       3.825     249.166
  FOR FCULT = 5.500   AND,    25.   STRANDS    UMP =    1841.
     6.000      270.000       4.318      25.348       0.002       3.519     252.430
     6.000      270.000       4.492      25.348       0.003       3.672     251.666
     6.000      270.000       4.665      25.348       0.003       3.825     250.902
  FOR FCULT = 6.000   AND,    25.   STRANDS    UMP =    1867.
```

FIG.— 3. COMPUTER OUTPUT — DESIGN

```
   PORTLAND CEMENT ASSOC.,                  JOB NO. 65   DATE
     DESIGN SECTION                         STRUCTURE   2FT9 BOX   30FT SPAN
                                            SUBJECT
PRESTRESSED GIRDER ANALYSIS                 DATA BY   CLF   CHECKED BY

 BOX WIDTH =    4.000FT.  BOX DEPTH =   2.750FT.   TOP SLAB =   5.500IN.   BOT SLAB =   5.500IN.
 SIDE WALL =    5.000IN.  CEN. WALL =   0.000IN.     FILLET =   3.000IN.      DELTA =   0.000IN.

 SECTION PROPERTIES
 AREA =      766.00    YB =    16.500    YT =    16.500
    I =    111838.     SB =    6778.0    ST =    6778.0     Q =    4325.0
 STRESSES IN EXTREME FIBERS DUE TO EXTERNAL LOADS
 DIST          BEAM WT                SDL              LIVE LOAD               TOTAL
             TOP        BOT       TOP       BOT       TOP       BOT        TOP       BOT
0.500 L     0.158    -0.158     0.146    -0.146     1.160    -1.160     1.465    -1.465
0.333 L     0.141    -0.141     0.129    -0.129     1.063    -1.063     1.334    -1.334
0.250 L     0.119    -0.119     0.109    -0.109     0.876    -0.876     1.105    -1.105
0.000 L     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000

 CASE  5 STRESSES     26. STRANDS     YM =    7.651    YE =    7.651
 DIST   INITIAL PRESTRESS        BEAM WT +       BEAM WT + SDL +      ALL LOADS +
                              INITIAL PRESTRESS  FINAL PRESTRESS   FINAL PRESTRESS
             TOP        BOT       TOP       BOT       TOP       BOT        TOP       BOT
0.500 L    -0.000     1.825     0.158     1.666     0.305     1.292     1.465     0.132
0.333 L    -0.000     1.825     0.141     1.684     0.271     1.326     1.334     0.263
0.250 L    -0.000     1.825     0.119     1.706     0.228     1.369     1.105     0.492
0.000 L    -0.000     1.825    -0.000     1.825    -0.000     1.597    -0.000     1.597
 CHECK CONVENTIONAL TENSILE REINF. AT TOP SLAB.
 ULTIMATE MOMENT REQUIRED =    1831.    ULTIMATE MOMENT PROVIDED =    1856.
 AT 1/4 PT,REQ. STIRRUP SPACING =    8.84 IN.        DT =  0.441 KSI
 AT 1/3 PT,REQ. STIRRUP SPACING =   12.07 IN.        DT =  0.313 KSI
 DEFLECTIONS
 BM WT + PRESTRESS = -0.201   TOTAL DL + PRESTRESS = -0.144   LIVE LOAD =  0.220
```

FIG. — 4. COMPUTER OUTPUT — ANALYSIS

DESIGN CRITERIA

The design criteria conform to the American Railway Engineering Association (AREA) specifications. In general, the designs are extensions of box-beam specifications previously adopted by the AREA. However, tables are presented for beams with tension in the top slab contrary to the tension criteria used in published AREA specifications for beams with straight parallel strands.

The specific design criteria used are as follows:

Concrete Strength

Beams with straight parallel strands with and without tension in the top slab:

At release of strands	4,000 psi
At 28 days	5,000 psi

Beams with harped strands:

At release of strands	4,500 psi
At 28 days	5,000 psi

Allowable Concrete Stresses

Beams with straight parallel strands with tension in the top slab:

Temporary:	Compression	$0.60 f_{ci}$
	Tension in top slab with nonprestressed reinforcement	$6\sqrt{f_{ci}}$
	Tension in top slab without nonprestressed reinforcement	$3\sqrt{f_{ci}}$
	Tension in bottom slab	Zero
Final:	Compression	$0.40 f'_c$
	Tension in bottom slab	Zero

Beams with harped strands:

Temporary:	Compression	$0.60 f_{ci}$
	Tension in top slab with nonprestressed reinforcement	$6\sqrt{f_{ci}}$
	Tension in top slab without nonprestressed reinforcement	$3\sqrt{f_{ci}}$
	Tension in bottom slab	Zero
Final:	Compression	$0.40 f'_c$
	Tension under design dead load	Zero

Beams with straight parallel strands without tension in the top slab:

Temporary:	Compression	$0.60 f_{ci}$
	Tension	Zero
Final:	Compression	$0.40 f_{ci}$
	Tension	Zero

Prestressing Strand—½ in. ϕ 270 K

Ultimate strength	270,000 psi
Area	0.153 sq in

Allowable Stresses in Prestressing Steel

Temporary immediately after transfer	$0.70 f'_s$
Effective prestress	$0.57 f'_s$

Note: Seven percent reduction in the initial prestressing force is allowed for elastic shortening of the girder and for strand relaxation prior to computing stresses due to the prestress force at release.

Allowable Stresses in Nontensioned Reinforcement

Shear reinforcement (at ultimate)	40,000 psi
Other	20,000 psi

Diagonal Tension

The values of diagonal tension shown in the tables were calculated using the *ultimate* unit shearing stress and considering the prestressing force to be that at working loads after all losses.

Live Load

Cooper E 72. Fractions of one track of E 72 loading applied to various box widths are as follows:

Width of Box	*Fraction of E 72 Loading*
3′–0″	0.25
4′–0″	0.33
6′–0″	0.50
7′–0″	0.50
7′–6″	0.50

Impact Loading

Impact loading fractions were computed from the formula:

$$I = 35 - \frac{L^2}{500}$$

where: L = design span in feet.
I = impact loading in percent of live load.

Dead Load

Concrete: 150 lb per cu ft
Ballast and Ties: 120 lb per cu ft (1′-3″ depth over width of box)
Track and associated details:

Width of Box	*Track Weight Lb per Lin. Ft*
3′-0″	50
4′-0″	67
6′-0″	100
7′-0″	100
7′-6″	100

Diaphragm weight: Diaphragm weight was not included in the designs for straight parallel strands. However, weight of diaphragms has a negligible effect on stresses, and diaphragms may be used without any change in the design table values. Weight of diaphragms 8 in thick was included at the ⅓ span points in designs with harped strands. End diaphragms shall be included for spans in excess of 40 ft unless an analysis is made to develop reinforcement details for a through-voided section.

Miscellaneous: An allowance of 10 percent of the weight of ballast, ties and track was made in the dead-load calculations to provide for handrail, drainage slope on the top of the box sections, and other details not covered above.

Total superimposed dead load (exclusive of the weight of the box section itself):

Width of Box	*Superimposed Dead Load Kips per Lin. Ft*
3′-0″	0.550
4′-0″	0.734
6′-0″	1.100
7′-0″	1.220
7′-6″	1.350

Deflections

Deflections are calculated using a modulus of elasticity at release of: $E = 1{,}800{,}000 + 500\ (4{,}000) = 3{,}800{,}000$ psi, and a 28-day modulus of elasticity of: $E = 1{,}800{,}000 + 500\ (5{,}000) = 4{,}300{,}000$ psi.

No allowance was made for long-time deflections.

NOMENCLATURE

CG = Center of gravity.

f'_c = Concrete cylinder strength at 28 days.

f_{ci} = Concrete cylinder strength at release of strands.

f'_s = Ultimate strength of prestressing steel.

I = Moment of inertia.

Q = First moment about neutral axis of area above neutral axis. ($Q = \Sigma Ay$) Used in formula $v = VQ/Ib$, where v = unit shear stress in psi, V = external shear in pounds, I = moment of inertia in inches^4, and b = total width of concrete walls at the neutral axis.

SB = Bottom section modulus.

SPAN = Distance center to center of bearings.

ST = Top section modulus.

TBS = Thickness of bottom slab.

TTS = Thickness of top slab.

TSW = Thickness of side walls.

YB = Distance from neutral axis to bottom of beam.

YE = Distance from bottom of beam to center of gravity of strands at the beam ends for designs with harped strands.

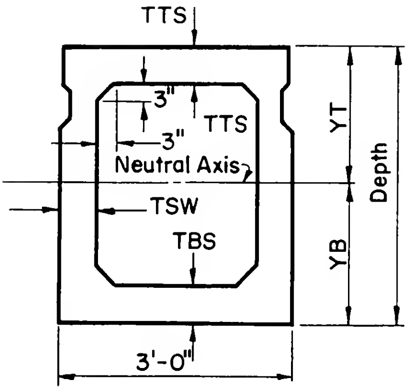
YM = Distance from bottom of beam to center of gravity of strands at the ⅓ span point for designs with harped strands.

YT = Distance from neutral axis to top of beam.

¼ Pt. = One-quarter span point from support.

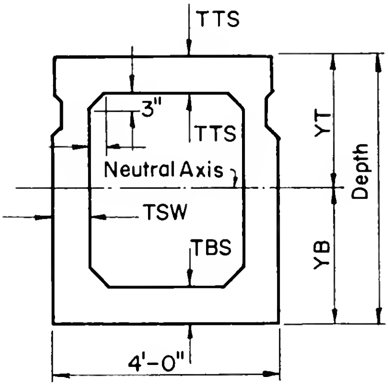
⅓ Pt. = One-third span point from support.

SECTION PROPERTIES -- 3'-0" WIDE SINGLE BOX



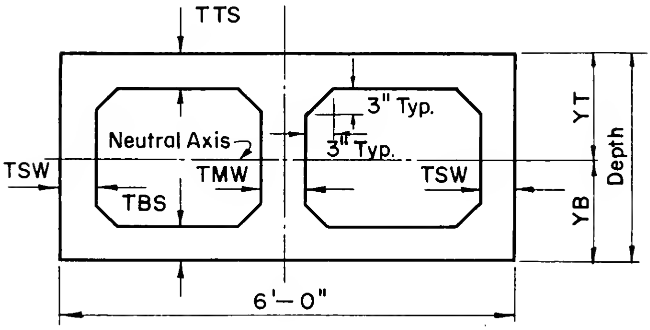
Depth in.	TTS in.	TBS in.	TSW in.	Area $in.^2$	Weight Kips/LF	YB & YT in.	I $in.^4$	SB & ST $in.^3$	Q $in.^3$
33	5.50	5.50	5.00	634	0.661	16.50	86,549	5,245	3,417
36	5.50	5.50	5.00	664	0.692	18.00	108,503	6,028	3,904
39	5.50	5.50	5.00	694	0.723	19.50	133,445	6,843	4,413
42	5.50	5.50	5.00	724	0.755	21.00	161,510	7,690	4,945
45	5.50	5.50	5.00	754	0.785	22.50	192,833	8,570	5,499
48	5.50	5.50	5.00	784	0.816	24.00	227,549	9,481	6,076
54	6.00	6.00	5.00	870	0.907	27.00	319,077	11,817	7,569
60	6.00	6.00	5.00	930	0.969	30.00	417,915	13,930	8,919
66	6.00	6.00	5.00	990	1.030	33.00	533,493	16,166	10,359
72	6.00	6.00	5.00	1,050	1.093	36.00	666,891	18,524	11,889
78	6.00	6.00	5.00	1,110	1.157	39.00	819,189	21,004	13,509

SECTION PROPERTIES -- 4'-0" WIDE SINGLE BOX



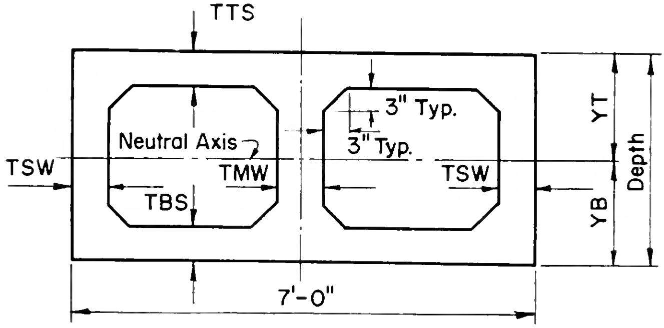
Depth in.	TTS in.	TBS in.	TSW in.	Area in.^{2}	Weight Kips/LF	YB & YT in.^{3}	I in.^{4}	SB & ST in.^{3}	Q in.^{3}
33	5.50	5.50	5.00	766	0.789	16.50	111,838	6,778	4,325
36	5.50	5.50	5.00	796	0.830	18.00	139,534	7,752	4,911
39	5.50	5.50	5.00	826	0.860	19.50	170,812	8,760	5,519
42	5.50	5.50	5.00	856	0.891	21.00	205,807	9,800	6,150
45	5.50	5.50	5.00	886	0.922	22.50	244,654	10,873	6,803
48	5.50	5.50	5.00	916	0.954	24.00	287,488	11,979	7,479
54	6.00	6.00	5.50	1,056	1.100	27.00	408,627	15,134	9,517
60	6.00	6.00	5.50	1,122	1.170	30.00	532,539	17,751	11,151
66	6.00	6.00	5.50	1,188	1.238	33.00	676,647	20,504	12,883
72	6.00	6.00	5.50	1,254	1.308	36.00	842,139	23,392	14,715
78	6.00	6.00	5.50	1,320	1.375	39.00	1,030,203	26,415	16,645

SECTION PROPERTIES -- 6'-0" WIDE DOUBLE BOX



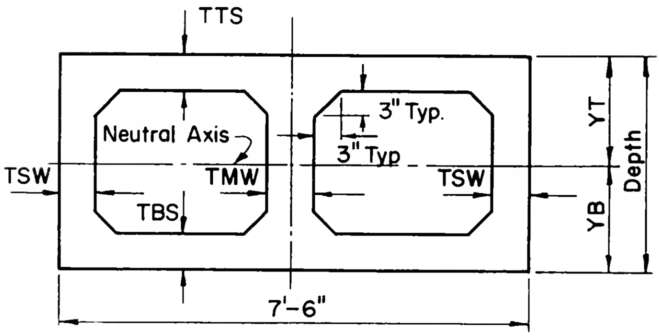
Depth in.	TTS in.	TBS in.	TSW in.	TMW in.	Area in.^{2}	Weight Kips/LF	YB & YT in.	I in.^{4}	SB & ST in.^{3}	Q in.^{3}
33	5.50	5.50	5.00	7.00	1,202	1.252	16.50	170,436	10,329	6,653
36	5.50	5.50	5.00	7.00	1,253	1.308	18.00	213,100	11,839	7,574
39	5.50	5.50	5.00	7.00	1,304	1.360	19.50	261,402	13,405	8,533
42	5.50	5.50	5.00	7.00	1,355	1.411	21.00	315,572	15,027	9,530
45	5.50	5.50	5.00	7.00	1,406	1.467	22.50	375,840	16,704	10,565
48	5.50	5.50	5.00	7.00	1,457	1.519	24.50	442,435	18,434	11,639

SECTION PROPERTIES -- 7'0" WIDE DOUBLE BOX



Depth in.	TTS in.	TBS in.	TSW in.	TMW in.	Area $in.^2$	Weight Kips/LF	YB & YT in.	I $in.^4$	SB & ST $in.^3$	Q $in.^3$
33	5.50	5.50	5.00	7.00	1,334	1.390	16.50	195,725	11,862	7,561
36	5.50	5.50	5.00	7.00	1,385	1.441	18.00	244,131	13,562	8,580
39	5.50	5.50	5.00	7.00	1,436	1.495	19.50	298,769	15,321	9,638
42	5.50	5.50	5.00	7.00	1,487	1.548	21.00	359,869	17,136	10,734
45	5.50	5.50	5.00	7.00	1,538	1.600	22.50	427,661	19,007	11,869
48	5.50	5.50	5.00	7.00	1,589	1.652	24.00	502,374	20,932	13,041

SECTION PROPERTIES -- 7'-6" WIDE DOUBLE BOX



Depth in.	TTS in.	TBS in.	TSW in.	TMW in.	Area $in.^2$	Weight Kips/LF	YB & YT in.	I $in.^4$	SB & ST $in.^3$	Q $in.^3$
33	5.50	5.50	5.00	7.00	1,400	1.458	16.50	208,370	12,628	8,014
36	5.50	5.50	5.00	7.00	1,451	1.512	18.00	259,646	14,424	9,083
39	5.50	5.50	5.00	7.00	1,502	1.565	19.50	317,453	16,279	10,191
42	5.50	5.50	5.00	7.00	1,553	1.619	21.00	382,018	18,191	11,336
45	5.50	5.50	5.00	7.00	1,604	1.671	22.50	453,572	20,158	12,520
48	5.50	5.50	5.00	7.00	1,655	1.723	24.00	532,344	22,180	13,742

DESIGN DATA - 3'0" WIDE SINGLE BOX, STRAIGHT STRANDS

Span ft.	Depth of Box in.	No. of 1/2"♦ 270k Strands	C.G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.		Maximum Tensile Stress kips per sq. in.		Ultimate Moment ft. kips		Diagonal Tension kips per sq. in.		Area of Stirrups in.²	Required Stirrup Spacing - in.		Deflections - in.		
				Initial Prestress	Final Prestress + All Loads	Initial Prestress	Final Prestress	Required	Provided	1/4 pt.	1/3 pt.		1/4 pt.	1/3 pt.	Beam Wt. + Prestress	Total DL + Prestress	Live Load
26	33	12	2.780	1.353	1.184	-0.335	-0.293	1,094	1,129	0.242	0.171	0.62	21.65	24.79	-0.141	-0.106	0.127
27	33	13	3.290	1.431	1.253	-0.329	-0.287	1,164	1,190	0.250	0.176	0.62	19.93	24.79	-0.158	-0.118	0.145
28	33	14	3.670	1.514	1.325	-0.327	-0.286	1,237	1,253	0.256	0.180	0.62	18.62	24.79	-0.177	-0.131	0.165
29	33	16	4.010	1.703	1.490	-0.345	-0.302	1,315	1,389	0.254	0.178	0.62	17.40	24.79	-0.213	-0.159	0.188
29	36	14	3.440	1.476	1.292	-0.342	-0.299	1,321	1,407	0.230	0.161	0.62	21.65	24.79	-0.173	-0.129	0.150
30	33	17	4.310	1.783	1.561	-0.341	-0.298	1,393	1,445	0.260	0.181	0.62	16.42	24.30	-0.235	-0.174	0.213
30	36	15	3.830	1.555	1.361	-0.340	-0.298	1,400	1,476	0.234	0.164	0.62	20.30	24.79	-0.192	-0.142	0.170
31	33	18	4.570	1.864	1.631	-0.337	-0.295	1,472	1,501	0.265	0.184	0.62	15.50	22.85	-0.259	-0.191	0.240
31	36	16	4.180	1.654	1.430	-0.338	-0.296	1,477	1,543	0.238	0.166	0.62	19.20	24.79	-0.212	-0.157	0.192
32	33	20	4.800	2.048	1.792	-0.351	-0.307	1,552	1,621	0.264	0.183	0.62	14.78	21.40	-0.302	-0.223	0.269
32	36	17	4.440	1.713	1.499	-0.336	-0.294	1,559	1,609	0.242	0.168	0.62	18.20	24.79	-0.234	-0.172	0.215
32	39	15	4.130	1.493	1.306	-0.330	-0.289	1,567	1,620	0.222	0.155	0.62	22.20	24.79	-0.191	-0.140	0.175
33	33	21	5.000	2.128	1.863	-0.347	-0.304	1,632	1,676	0.269	0.185	0.62	14.08	20.45	-0.330	-0.243	0.301
33	36	18	4.760	1.792	1.568	-0.334	-0.292	1,640	1,673	0.247	0.170	0.62	17.20	24.79	-0.257	-0.188	0.240
33	39	16	4.380	1.570	1.374	-0.330	-0.289	1,648	1,666	0.226	0.157	0.62	20.85	24.79	-0.211	-0.154	0.195
34	33	22	5.180	2.209	1.934	-0.343	-0.300	1,712	1,728	0.274	0.187	0.62	13.48	19.55	-0.360	-0.263	0.335
34	36	19	5.000	1.871	1.638	-0.332	-0.290	1,721	1,730	0.253	0.173	0.62	16.25	24.35	-0.282	-0.205	0.267
34	39	17	4.700	1.647	1.441	-0.329	-0.288	1,729	1,771	0.230	0.158	0.62	19.70	24.79	-0.232	-0.169	0.217
35	36	21	5.220	2.047	1.792	-0.346	-0.303	1,802	1,874	0.250	0.169	0.62	15.52	23.20	-0.326	-0.238	0.295
35	39	18	4.880	1.724	1.503	-0.329	-0.288	1,797	1,844	0.231	0.157	0.62	18.95	24.79	-0.257	-0.187	0.234
35	42	16	4.610	1.511	1.322	-0.322	-0.282	1,820	1,848	0.217	0.148	0.62	24.41	24.79	-0.210	-0.151	0.198
36	36	22	5.410	2.126	1.861	-0.344	-0.301	1,881	1,935	0.254	0.170	0.62	14.89	22.20	-0.355	-0.258	0.325
36	39	19	5.230	1.801	1.577	-0.329	-0.288	1,891	1,910	0.238	0.161	0.62	17.79	24.79	-0.279	-0.201	0.265
36	42	17	4.920	1.587	1.389	-0.324	-0.283	1,900	1,932	0.220	0.149	0.62	21.30	24.79	-0.231	-0.166	0.218
37	36	23	5.620	2.201	1.927	-0.338	-0.296	1,984	1,989	0.258	0.174	0.62	14.25	21.05	-0.383	-0.277	0.363
37	39	21	5.500	1.969	1.723	-0.341	-0.298	1,994	2,069	0.235	0.158	0.62	17.00	24.79	-0.321	-0.233	0.295
37	42	18	5.280	1.658	1.451	-0.320	-0.280	2,004	2,010	0.223	0.151	0.62	20.25	24.79	-0.251	-0.180	0.243
38	39	22	5.690	2.046	1.791	-0.341	-0.298	2,067	2,138	0.234	0.158	0.62	16.60	24.79	-0.349	-0.252	0.321
38	42	20	5.560	1.822	1.595	-0.336	-0.294	2,096	2,183	0.220	0.149	0.62	19.22	24.79	-0.291	-0.210	0.268
38	45	17	5.210	1.528	1.337	-0.315	-0.276	2,088	2,090	0.208	0.142	0.62	23.35	24.79	-0.228	-0.162	0.222

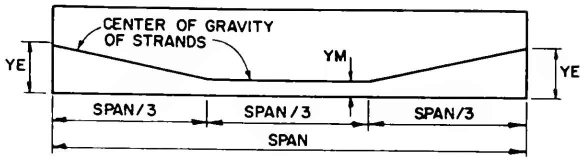
DESIGN DATA - 3'0" WIDE SINGLE BOX, STRAIGHT STRANDS (Cont'd.)

Span ft.	Depth of Box in.	No. of 1/2"φ 270 k Strands	C.G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.		Maximum Tensile Stress kips per sq. in.		Ultimate Moment ft. kips		Diagonal Tension kips per sq. in.		Area of Stirrups in.^{2}	Required Stirrup Spacing - in.		Deflections - in.		
				Initial Prestress	Final Prestress + All Loads	Initial Prestress	Final Prestress	Required	Provided	1/4 pt.	1/3 pt.		1/4 pt.	1/3 pt.	Beam Wt. + Prestress	Total DL+ Prestress	Live Load
39	39	23	5.900	2.120	1.856	-0.337	-0.295	2,161	2,202	0.237	0.160	0.62	15.90	23.80	-0.377	-0.270	0.353
39	42	21	5.820	1.894	1.658	-0.334	-0.292	2,192	2,261	0.222	0.151	0.62	18.35	24.79	-0.216	-0.227	0.295
39	45	19	5.540	1.688	1.478	-0.333	-0.291	2,183	2,281	0.205	0.139	0.62	21.95	24.79	-0.265	-0.191	0.244
40	39	25	6.100	2.285	2.000	-0.347	-0.304	2,283	2,333	0.242	0.162	0.62	14.80	22.00	-0.426	-0.307	0.393
40	42	22	6.020	1.969	1.723	-0.335	-0.293	2,274	2,338	0.222	0.149	0.62	17.90	24.79	-0.342	-0.245	0.321
40	45	20	5.850	1.758	1.538	-0.331	-0.290	2,286	2,369	0.208	0.140	0.62	20.90	24.79	-0.288	-0.205	0.269
41	42	23	6.250	2.040	1.786	-0.331	-0.290	2,376	2,408	0.226	0.151	0.62	17.10	24.79	-0.368	-0.262	0.353
41	45	21	6.130	1.827	1.599	-0.329	-0.288	2,389	2,454	0.211	0.141	0.62	19.95	24.79	-0.311	-0.221	0.295
41	48	19	5.910	1.626	1.423	-0.323	-0.282	2,394	2,452	0.199	0.134	0.62	23.35	24.79	-0.261	-0.185	0.249
42	42	25	6.490	2.197	1.922	-0.339	-0.297	2,502	2,553	0.230	0.153	0.62	15.95	24.20	-0.415	-0.297	0.390
42	45	22	6.390	1.896	1.660	-0.327	-0.286	2,492	2,535	0.214	0.143	0.62	19.10	24.79	-0.355	-0.237	0.323
42	48	20	6.220	1.694	1.483	-0.322	-0.282	2,497	2,549	0.201	0.134	0.62	22.30	24.79	-0.282	-0.199	0.273
43	42	26	6.680	2.267	1.984	-0.336	-0.294	2,606	2,613	0.234	0.155	0.62	15.30	23.15	-0.445	-0.316	0.425
43	45	23	6.620	1.966	1.721	-0.325	-0.285	2,596	2,613	0.217	0.144	0.62	18.32	24.79	-0.360	-0.254	0.352
43	48	21	6.500	1.762	1.542	-0.322	-0.281	2,601	2,642	0.203	0.135	0.62	21.40	24.79	-0.305	-0.214	0.297
44	45	25	6.830	2.120	1.856	-0.337	-0.295	2,700	2,778	0.216	0.143	0.62	17.45	24.79	-0.407	-0.289	0.383
44	48	22	6.760	1.830	1.602	-0.321	-0.321	2,706	2,732	0.203	0.136	0.62	20.05	24.79	-0.328	-0.230	0.323
45	45	26	7.030	2.189	1.916	-0.334	-0.293	2,805	2,846	0.219	0.145	0.62	16.75	24.79	-0.436	-0.307	0.416
45	48	23	7.000	1.897	1.661	-0.320	-0.280	2,811	2,818	0.207	0.138	0.62	19.65	24.79	-0.353	-0.246	0.351
46	45	27	7.210	2.258	1.976	-0.332	-0.290	2,911	2,912	0.223	0.148	0.62	16.10	24.40	-0.465	-0.327	0.451
46	48	25	7.220	2.047	1.792	-0.332	-0.290	2,918	2,999	0.206	0.137	0.62	18.75	24.79	-0.398	-0.280	0.380
46	54	21	6.621	1.623	1.420	-0.324	-0.284	2,946	3,059	0.187	0.125	0.62	24.79	24.79	-0.286	-0.200	0.271
47	48	26	7.420	2.114	1.850	-0.330	-0.289	3,023	3,075	0.209	0.139	0.62	18.02	24.79	-0.426	-0.298	0.411
48	48	27	7.600	2.182	1.909	-0.329	-0.288	3,130	3,149	0.213	0.141	0.62	17.30	24.79	-0.455	-0.316	0.443
48	54	23	7.188	1.747	1.529	-0.325	-0.285	3,154	3,277	0.189	0.126	0.62	23.33	24.79	-0.329	-0.229	0.314
49	48	29	7.780	2.328	2.038	-0.339	-0.297	3,243	3,302	0.214	0.141	0.62	16.41	24.79	-0.506	-0.354	0.478
50	54	25	7.700	1.870	1.637	-0.325	-0.284	3,377	3,478	0.193	0.127	0.62	21.56	24.79	-0.376	-0.260	0.364
52	54	27	8.143	1.993	1.744	-0.324	-0.283	3,605	3,666	0.196	0.129	0.62	20.04	24.79	-0.426	-0.292	0.420
54	54	29	8.532	2.115	1.851	-0.322	-0.282	3,839	3,841	0.201	0.131	0.62	18.67	24.79	-0.480	-0.326	0.481
54	60	25	8.561	1.757	1.538	-0.311	-0.272	3,879	3,916	0.183	0.120	0.62	23.97	24.79	-0.359	-0.241	0.367

DESIGN DATA - 3'0" WIDE SINGLE BOX, STRAIGHT STRANDS (Cont'd.)

Span ft.	Depth of Box in.	No. of 1/2"♦ 270k Strands	C.G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.		Maximum Tensile Stress kips per sq. in.		Ultimate Moment ft. kips		Diagonal Tension kips per sq. in.		Area of Stirrups in.^{2}	Required Stirrup Spacing - in.		Deflections - in.		
				Initial Prestress	Final Prestress + All Loads	Initial Prestress	Final Prestress	Required	Provided	1/4 pt.	1/3 pt.		1/4 pt.	1/3 pt.	Beam Wt. + Prestress	Total DL+ Prestress	Live Load
56	54	32	8.883	2.308	2.020	-0.330	-0.288	4,083	4,095	0.204	0.132	0.62	17.22	24.79	-0.560	-0.381	0.549
56	60	28	9.040	1.942	1.700	-0.323	-0.282	4,127	4,259	0.183	0.119	0.62	22.05	24.79	-0.426	-0.288	0.419
58	60	30	9.458	2.057	1.800	-0.322	-0.281	4,378	4,456	0.187	0.121	0.62	20.53	24.79	-0.476	-0.319	0.476
60	60	33	9.839	2.238	1.959	-0.330	-0.288	4,640	4,745	0.189	0.122	0.62	19.03	24.79	-0.552	-0.371	0.539
60	66	29	10.030	1.895	1.659	-0.320	-0.280	4,690	4,874	0.173	0.111	0.62	23.99	24.79	-0.424	-0.282	0.422
62	66	31	10.473	2.003	1.753	-0.319	-0.279	4,959	5,093	0.175	0.114	0.62	22.46	24.79	-0.47.	-0.312	0.475
64	66	33	10.865	2.111	1.848	-0.318	-0.278	5,231	5,299	0.178	0.116	0.62	21.11	24.79	-0.522	-0.342	0.533
64	72	30	11.094	1.853	1.621	-0.316	-0.276	5,287	5,512	0.164	0.106	0.62	24.79	24.79	-0.421	-0.276	0.426
66	66	36	11.253	2.280	1.995	-0.324	-0.283	5,540	5,600	0.180	0.117	0.62	19.60	24.79	-0.597	-0.393	0.601
66	72	33	11.589	2.014	1.763	-0.324	-0.283	5,599	5,888	0.164	0.106	0.62	24.08	24.79	-0.486	-0.320	0.480
68	72	35	11.973	2.117	1.853	-0.324	-0.283	5,869	6,112	0.167	0.108	0.62	22.61	24.79	-0.535	-0.350	0.533
68	78	32	12.242	1.871	1.638	-0.320	-0.280	5,931	6,331	0.155	0.100	0.62	24.79	24.79	-0.436	-0.285	0.434
70	72	37	12.337	2.218	1.941	-0.323	-0.283	6,157	6,320	0.170	0.109	0.62	21.33	24.79	-0.586	-0.380	0.591
70	78	34	12.699	1.968	1.723	-0.321	-0.281	6,223	6,588	0.156	0.101	0.62	24.79	24.79	-0.480	-0.311	0.481
72	72	39	12.666	2.319	2.030	-0.322	-0.282	6,448	6,516	0.173	0.111	0.62	20.18	24.79	-0.640	-0.411	0.654
72	78	36	13.112	2.065	1.807	-0.321	-0.280	6,517	6,831	0.158	0.102	0.62	24.45	24.79	-0.526	-0.338	0.532
74	78	38	13.488	2.161	1.892	-0.320	-0.280	6,817	7,061	0.161	0.103	0.62	23.11	24.79	-0.574	-0.366	0.587
76	78	40	13.840	2.257	1.976	-0.319	-0.279	7,130	7,278	0.163	0.105	0.62	21.81	24.79	-0.625	-0.395	0.646

DESIGN DATA - 3'0" WIDE SINGLE BOX, HARPED STRANDS



Span ft.	Depth of Box in.	No. of 1/2" 270 k Strands	YE in.	YM in.	Maximum Compressive Stress kips per sq. in. Initial Prestress	Maximum Compressive Stress kips per sq. in. Final Prestress + All Loads	Maximum Tensile Stress kips per sq. in. Initial Prestress + Beam Wt. at 1/3 span pt.	Ultimate Moment ft. kips Required	Ultimate Moment ft. kips Provided	Diagonal Tension kips per sq. in. 1/4 pt.	Diagonal Tension kips per sq. in. 1/3 pt.	Area of Stirrups in.	Required Stirrup Spacing - in. 1/4 pt.	Required Stirrup Spacing - in. 1/3 pt.	Deflections in. Beam Wt. + Prestress	Deflections in. Total Dead Load + Prestress	Deflections in. Live Load
60	66	26	16.670	5.000	1.594	1.236	-0.181	4,729	4,898	0.172	0.103	0.62	24.79	24.79	-0.404	-0.265	0.422
64	66	29	16.670	5.000	1.772	1.379	-0.196	5,272	5,371	0.173	0.104	0.62	23.94	24.79	-0.509	-0.332	0.533
64	72	27	18.357	5.000	1.528	1.210	-0.185	5,328	5,613	0.161	0.096	0.62	24.79	24.79	-0.415	-0.270	0.426
68	66	33	16.670	5.000	2.021	1.569	-0.228	5,846	5,954	0.173	0.103	0.62	21.77	24.79	-0.657	-0.430	0.666
68	72	29	18.357	5.000	1.667	1.329	-0.181	5,908	5,964	0.164	0.098	0.62	24.79	24.79	-0.494	-0.314	0.533
68	78	28	20.076	5.000	1.543	1.187	-0.186	5,974	6,364	0.152	0.090	0.62	24.79	24.79	-0.425	-0.275	0.434
70	66	35	16.670	5.000	2.144	1.664	-0.243	6,135	6,227	0.173	0.103	0.62	20.80	24.79	-0.739	-0.484	0.739
72	66	37	16.670	5.000	2.267	1.759	-0.257	6,423	6,486	0.174	0.103	0.62	19.94	24.79	-0.827	-0.541	0.817
72	72	33	18.357	5.000	1.904	1.479	-0.214	6,493	6,627	0.162	0.096	0.62	24.36	24.79	-0.634	-0.407	0.654
72	78	31	20.076	5.000	1.704	1.314	-0.202	6,562	6,936	0.151	0.089	0.62	24.79	24.79	-0.525	-0.338	0.532
74	66	39	16.670	5.000	2.389	1.854	-0.248	6,714	6,734	0.174	0.103	0.62	19.15	24.79	-0.921	-0.602	0.901
74	72	35	18.357	5.000	2.022	1.569	-0.229	6,787	6,938	0.162	0.096	0.62	23.38	24.79	-0.712	-0.458	0.720
76	66	42	16.670	5.000	2.584	1.997	-0.302	7,020	7,080	0.175	0.103	0.62	18.13	24.79	-1.054	-0.696	0.992
76	72	35	18.357	5.000	2.139	1.658	-0.244	7,097	7,236	0.162	0.096	0.62	22.35	24.79	-0.795	-0.512	0.794
76	78	33	20.076	5.000	1.795	1.413	-0.196	7,137	7,300	0.154	0.091	0.62	24.79	24.79	-0.612	-0.384	0.646
78	72	39	18.357	5.000	2.256	1.748	-0.258	7,407	7,522	0.163	0.096	0.62	21.36	24.79	-0.883	-0.570	0.871
78	78	35	20.076	5.000	1.908	1.481	-0.212	7,487	7,651	0.154	0.090	0.62	24.79	24.79	-0.686	-0.432	0.709
80	72	41	18.357	5.000	2.371	1.838	-0.271	7,723	7,795	0.164	0.096	0.62	20.45	24.79	-0.977	0.630	0.954
80	78	37	20.076	5.000	2.020	1.569	-0.227	7,807	7,988	0.154	0.090	0.62	24.68	24.79	-0.764	-0.484	0.777
82	78	38	20.076	5.000	2.063	1.611	-0.222	8,124	8,152	0.156	0.090	0.62	23.84	24.79	-0.817	-0.510	0.847
84	78	40	20.076	5.000	2.174	1.696	-0.236	8,457	8,470	0.157	0.090	0.62	22.75	24.79	-0.904	-0.566	0.925

DESIGN DATA - 4'0" WIDE SINGLE BOX, STRAIGHT STRANDS

Span ft.	Depth of Box in.	No. of 1/2"♦ 270 k Strands	C.G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.		Maximum Tensile Stress kips per sq. in.		Ultimate Moment ft. kips		Diagonal Tension kips per sq. in.		Area of Stirrups in.^{2}	Required Stirrup Spacing - in.		Deflections - in.		
				Initial Prestress	Final Prestress + All Loads	Initial Prestress	Final Prestress	Required	Provided	1/4 pt.	1/3 pt.		1/4 pt.	1/3 pt.	Beam Wt. + Prestress	Total DL+ Prestress	Live Load
26	33	15	2.250	1.374	1.203	-0.321	-0.281	1,442	1,447	0.347	0.249	0.62	14.18	20.58	-0.145	-0.109	0.131
27	33	17	2.479	1.542	1.350	-0.348	-0.305	1,532	1,607	0.347	0.248	0.62	13.41	19.26	-0.178	-0.132	0.150
28	33	18	2.870	1.605	1.405	-0.341	-0.298	1,628	1,667	0.358	0.256	0.62	12.66	18.02	-0.193	-0.144	0.171
29	33	20	3.224	1.755	1.536	-0.351	-0.307	1,729	1,805	0.361	0.257	0.62	11.97	16.88	-0.224	-0.168	0.195
29	36	17	2.512	1.487	1.302	-0.339	-0.296	1,735	1,780	0.327	0.234	0.62	14.53	21.07	-0.177	-0.132	0.156
30	33	21	3.531	1.817	1.591	-0.343	-0.300	1,831	1,861	0.371	0.263	0.62	11.42	16.00	-0.244	-0.182	0.220
30	36	18	2.925	1.549	1.356	-0.333	-0.291	1,837	1,848	0.335	0.236	0.62	13.78	19.82	-0.194	-0.144	0.176
31	33	23	3.800	1.966	1.721	-0.351	-0.307	1,933	1,991	0.373	0.264	0.62	10.89	15.17	-0.280	-0.209	0.248
31	36	20	3.285	1.696	1.485	-0.345	-0.302	1,940	2,006	0.336	0.239	0.62	13.09	18.66	-0.225	-0.168	0.199
32	33	24	4.037	2.029	1.776	-0.344	-0.301	2,035	2,045	0.381	0.269	0.62	10.48	14.53	-0.304	-0.225	0.278
32	36	21	3.600	1.758	1.539	-0.339	-0.297	2,043	2,071	0.343	0.243	0.62	12.55	17.78	-0.245	-0.181	0.222
32	39	19	2.007	1.580	1.383	-0.343	-0.300	2,050	2,130	0.309	0.219	0.62	14.89	21.64	-0.208	-0.154	0.182
33	33	26	4.250	2.176	1.905	-0.350	-0.307	2,139	2,158	0.388	0.271	0.62	9.94	13.79	-0.344	-0.254	0.310
33	36	23	3.882	1.903	1.666	-0.349	-0.305	2,147	2,220	0.345	0.242	0.62	11.93	16.91	-0.281	-0.208	0.248
33	39	20	3.374	1.641	1.436	-0.339	-0.296	2,155	2,205	0.317	0.223	0.62	14.15	20.56	-0.226	-0.167	0.203
34	33	28	4.440	2.322	2.033	-0.356	-0.312	2,244	2,287	0.389	0.269	0.62	9.58	13.32	-0.388	-0.286	0.344
34	36	24	4.133	1.965	1.720	-0.343	-0.300	2,252	2,283	0.353	0.246	0.62	11.44	16.22	-0.304	-0.223	0.276
34	39	21	3.701	1.702	1.489	-0.334	-0.293	2,261	2,280	0.324	0.226	0.62	13.51	19.62	-0.246	-0.180	0.225
35	36	26	4.355	2.109	1.846	-0.352	-0.308	2,355	2,416	0.357	0.246	0.62	10.91	15.48	-0.343	-0.253	0.308
35	39	23	3.987	1.844	1.614	-0.346	-0.303	2,364	2,448	0.324	0.224	0.62	12.92	18.74	-0.281	-0.206	0.249
35	42	20	3.489	1.589	1.391	-0.332	-0.291	2,373	2,403	0.301	0.210	0.62	15.16	22.57	-0.227	-0.165	0.206
36	36	27	4.553	2.171	1.900	-0.347	-0.304	2,458	2,482	0.362	0.248	0.62	10.56	15.00	-0.370	-0.270	0.336
36	39	24	4.242	1.905	1.667	-0.342	-0.300	2,467	2,519	0.330	0.227	0.62	12.42	18.03	-0.303	-0.221	0.274
36	42	21	3.812	1.650	1.444	-0.330	-0.289	2,476	2,487	0.307	0.212	0.62	14.53	21.61	-0.246	-0.178	0.227
37	36	29	4.774	2.309	2.021	-0.350	-0.306	2,590	2,618	0.363	0.249	0.62	10.18	14.34	-0.413	-0.301	0.374
37	39	26	4.532	2.041	1.786	-0.348	-0.304	2,600	2,667	0.332	0.228	0.62	11.86	17.03	-0.341	-0.249	0.305
37	42	23	4.178	1.784	1.561	-0.399	-0.296	2,610	2,669	0.307	0.212	0.62	13.88	20.38	-0.279	-0.203	0.253
38	39	27	4.759	2.100	1.838	-0.342	-0.300	2,717	2,740	0.337	0.232	0.62	11.51	16.39	-0.366	-0.266	0.336
38	42	24	4.466	1.842	1.613	-0.334	-0.293	2,727	2,747	0.311	0.215	0.62	13.38	19.47	-0.301	-0.218	0.279
38	45	22	4.064	1.670	1.462	-0.335	-0.293	2,738	2,800	0.287	0.199	0.62	15.44	23.01	-0.258	-0.187	0.234

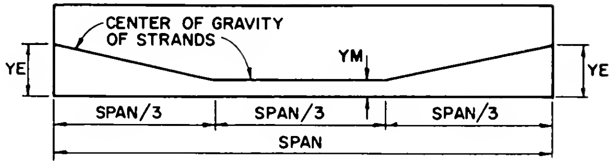
DESIGN DATA - 4'0" WIDE SINGLE BOX, STRAIGHT STRANDS (Cont'd.)

Span ft.	Depth of Box in.	No. of 1/2"ϕ 270k Strands	C.G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in. Initial Prestress	Maximum Compressive Stress kips per sq. in. Final Prestress + All Loads	Maximum Tensile Stress kips per sq. in. Initial Prestress	Maximum Tensile Stress kips per sq. in. Final Prestress	Ultimate Moment ft. kips Required	Ultimate Moment ft. kips Provided	Diagonal Tension kips per sq. in. 1/4 pt.	Diagonal Tension kips per sq. in. 1/3 pt.	Area of Stirrups in.²	Required Stirrup Spacing - in. 1/4 pt.	Required Stirrup Spacing - in. 1/3 pt.	Deflections - in. Beam Wt. + Prestress	Deflections - in. Total DL+ Prestress	Deflections - in. Live Load
39	39	29	4.974	2.237	1.958	-0.349	-0.305	2,839	2,894	0.337	0.231	0.62	11.10	15.72	-0.408	-0.297	0.369
39	42	26	4.735	1.977	1.730	-0.343	-0.300	2,850	2,916	0.312	0.215	0.62	12.81	18.49	-0.338	-0.245	0.306
39	45	23	4.398	1.727	1.512	-0.331	-0.290	2,861	2,887	0.292	0.202	0.62	14.83	21.92	-0.278	-0.200	0.258
40	39	30	5.143	2.299	2.012	-0.345	-0.302	2,943	2,960	0.339	0.231	0.62	10.86	15.41	-0.437	-0.315	0.401
40	42	27	4.992	2.034	1.780	-0.337	-0.295	2,980	2,995	0.318	0.218	0.62	12.36	17.82	-0.362	-0.261	0.337
40	45	25	4.715	1.858	1.626	-0.340	-0.298	2,992	3,070	0.294	0.202	0.62	14.09	20.74	-0.313	-0.226	0.283
41	42	29	5.220	2.355	1.896	-0.344	-0.301	3,109	3,166	0.318	0.216	0.62	11.92	17.17	-0.403	-0.291	0.368
41	45	26	4.997	1.914	1.675	-0.336	-0.294	3,121	3,160	0.298	0.204	0.62	13.63	20.03	-0.335	-0.241	0.310
41	48	24	4.683	1.745	1.527	-0.336	-0.294	3,133	3,201	0.280	0.191	0.62	15.43	23.17	-0.289	-0.208	0.264
42	42	31	5.435	2.297	2.011	-0.350	-0.306	3,244	3,324	0.320	0.216	0.62	11.44	16.45	-0.447	-0.323	0.403
42	45	28	5.262	2.043	1.788	-0.343	-0.300	3,256	3,355	0.298	0.202	0.62	13.12	19.25	-0.373	-0.269	0.339
42	48	25	5.006	1.800	1.575	-0.332	-0.290	3,269	3,302	0.284	0.193	0.62	14.89	22.30	-0.310	-0.222	0.288
43	45	29	5.497	2.099	1.837	-0.339	-0.296	3,388	3,436	0.302	0.204	0.62	12.70	18.60	-0.398	-0.285	0.369
43	48	26	5.291	1.855	1.623	-0.328	-0.287	3,401	3,402	0.287	0.194	0.62	14.42	21.56	-0.331	-0.235	0.314
44	45	31	5.712	2.228	1.950	-0.346	-0.303	3,520	3,611	0.303	0.204	0.62	12.25	17.84	-0.440	-0.316	0.401
44	48	28	5.551	1.981	1.734	-0.337	-0.295	3,534	3,614	0.285	0.192	0.62	13.95	20.73	-0.369	-0.264	0.341
45	45	32	5.911	2.284	1.999	-0.341	-0.299	3,655	3,683	0.308	0.208	0.62	11.87	17.14	-0.468	-0.333	0.435
45	48	29	5.793	2.036	1.782	-0.333	-0.292	3,669	3,703	0.289	0.195	0.62	13.51	19.90	-0.393	-0.279	0.370
46	48	31	6.013	2.161	1.892	-0.341	-0.299	3,803	3,895	0.288	0.195	0.62	13.06	19.06	-0.434	-0.309	0.400
46	54	26	5.238	1.710	1.497	-0.331	-0.289	3,852	3,945	0.262	0.179	0.62	16.70	24.79	-0.309	-0.219	0.286
47	48	32	6.214	2.217	1.940	-0.338	-0.296	3,936	3,976	0.292	0.198	0.62	12.66	18.38	-0.461	-0.326	0.432
48	54	28	5.820	1.812	1.586	-0.327	-0.286	4,123	4,152	0.270	0.183	0.62	15.56	23.47	-0.349	-0.245	0.332
50	54	31	6.347	1.977	1.730	-0.332	-0.291	4,415	4,500	0.271	0.182	0.62	14.62	21.91	-0.409	-0.286	0.385
52	54	34	6.804	2.140	1.873	-0.337	-0.295	4,712	4,817	0.274	0.183	0.62	13.74	20.46	-0.474	-0.331	0.443
54	54	37	7.206	2.302	2.015	-0.340	-0.297	5,016	5,104	0.279	0.186	0.62	12.89	18.99	-0.543	-0.378	0.508
54	60	31	7.050	1.873	1.639	-0.320	-0.280	5,057	5,062	0.255	0.171	0.62	16.04	24.57	-0.397	-0.271	0.390
56	60	34	7.541	2.028	1.775	-0.325	-0.285	5,379	5,427	0.258	0.171	0.62	15.06	22.85	-0.458	-0.313	0.446
58	60	37	7.972	2.182	1.910	-0.330	-0.288	5,705	5,762	0.262	0.173	0.62	14.14	21.28	-0.524	-0.357	0.506

DESIGN DATA - 4'0" WIDE SINGLE BOX, STRAIGHT STRANDS (Cont'd.)

Span ft.	Depth of Box in.	No. of 1/2"ϕ 270 k Strands	C.G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.		Maximum Tensile Stress kips per sq. in.		Ultimate Moment ft. kips		Diagonal Tension kips per sq. in.		Area of Stirrups in.^{2}	Required Stirrup Spacing - in.		Deflections - in.		
				Initial Prestress	Final Prestress + All Loads	Initial Prestress	Final Prestress	Required	Provided	1/4 pt.	1/3 pt.		1/4 pt.	1/3 pt.	Beam Wt. + Prestress	Total DL+ Prestress	Live Load
60	60	40	9.364	2.335	2.044	-0.332	-0.291	6,046	6,065	0.266	0.175	0.62	13.31	19.87	-0.594	-0.404	0.573
60	66	35	8.388	1.982	1.734	-0.322	-0.281	6,096	6,175	0.242	0.160	0.62	16.25	24.79	-0.458	-0.309	0.452
62	66	38	8.841	2.129	1.863	-0.326	-0.285	6,445	6,546	0.244	0.161	0.62	15.34	23.36	-0.521	-0.351	0.509
64	66	41	9.244	2.275	1.991	-0.330	-0.289	6,797	6,886	0.247	0.164	0.62	14.50	21.73	-0.589	-0.396	0.571
64	72	36	9.320	1.939	1.697	-0.317	-0.277	6,853	6,944	0.228	0.152	0.62	17.49	24.79	-0.458	-0.304	0.460
66	72	39	9.828	2.077	1.818	-0.320	-0.280	7,258	7,346	0.231	0.153	0.62	16.47	24.79	-0.517	-0.343	0.518
68	72	42	10.219	2.217	1.941	-0.326	-0.285	7,606	7,726	0.234	0.154	0.62	15.57	23.68	-0.582	-0.386	0.575
68	78	38	10.352	1.949	1.706	-0.319	-0.279	7,668	7,903	0.216	0.143	0.62	18.46	24.79	-0.472	-0.311	0.470
70	78	40	10.816	2.032	1.779	-0.317	-0.277	8,044	8,176	0.219	0.144	0.62	17.59	24.79	-0.514	-0.335	0.522
72	78	43	11.235	2.166	1.896	-0.322	-0.282	8,423	8,590	0.221	0.145	0.62	16.70	24.79	-0.576	-0.376	0.577
74	78	45	11.619	2.249	1.968	-0.319	-0.279	8,809	8,830	0.225	0.148	0.62	15.96	24.35	-0.623	-0.402	0.636

DESIGN DATA - 4'0" WIDE SINGLE BOX, HARPED STRANDS



Span ft.	Depth of Box in.	No. of 1/2" 270k Strands	YE in.	YM in.	Maximum Compressive Stress kips per sq.in.		Maximum Tensile Stress kips per sq.in.	Ultimate Moment ft. kips		Diagonal Tension kips per sq.in.		Area of Stirrups in.	Required Stirrup Spacing - in.		Deflections in.		
					Initial Prestress	Final Prestress + All Loads	Initial Prestress + Beam Wt. at 1/3 span pt.	Required	Provided	1/4 pt.	1/3 pt.		1/4 pt.	1/3 pt.	Beam Wt. + Prestress	Total Dead Load + Prestress	Live Load
60	66	33	15.269	5.000	1.717	1.369	-0.151	6,149	6,255	0.246	0.152	0.62	16.58	24.79	-0.429	-0.284	0.452
64	66	37	15.269	5.000	1.921	1.536	-0.198	6,853	6,891	0.247	0.153	0.62	15.43	24.79	-0.546	-0.359	0.571
64	72	34	16.826	5.000	1.689	1.340	-0.157	6,909	7,117	0.229	0.142	0.62	18.10	24.79	-0.441	-0.290	0.460
68	66	42	15.269	5.000	2.184	1.743	-0.192	7,598	7,614	0.249	0.153	0.62	14.22	22.83	-0.702	-0.463	0.713
68	72	38	16.826	5.000	1.885	1.519	-0.173	7,660	7,819	0.229	0.142	0.62	16.86	24.79	-0.557	-0.365	0.574
68	78	35	18.424	5.000	1.661	1.313	-0.160	7,722	8,016	0.215	0.132	0.62	19.53	24.79	-0.452	-0.294	0.470
72	72	42	16.826	5.000	2.079	1.656	-0.187	8,415	8,470	0.232	0.142	0.62	15.68	24.79	-0.686	-0.446	0.705
72	78	38	18.424	5.000	1.793	1.426	-0.163	8,484	8,598	0.217	0.133	0.62	18.34	24.79	-0.545	-0.349	0.577
74	72	45	16.826	5.000	2.234	1.774	-0.207	8,794	8,924	0.231	0.121	0.62	15.07	24.58	-0.780	-0.511	0.776
76	72	47	16.826	5.000	2.330	1.853	-0.212	9,195	9,212	0.233	0.142	0.62	14.54	23.55	-0.857	-0.559	0.855
76	78	42	18.424	5.000	1.979	1.576	-0.178	9,271	9,327	0.218	0.133	0.62	17.14	24.79	-0.670	-0.428	0.700
78	72	50	16.826	5.000	2.483	1.971	-0.231	9,575	9,620	0.235	0.142	0.62	13.91	22.41	-0.964	-0.632	0.939
78	78	45	18.424	5.000	2.129	1.689	-0.199	9,676	9,840	0.218	0.132	0.62	16.42	24.79	-0.761	-0.491	0.769
80	78	47	18.424	5.000	2.221	1.764	-0.205	10,087	10,166	0.220	0.132	0.62	15.86	24.79	-0.834	-0.536	0.842
82	78	50	18.424	5.000	2.369	1.877	-0.224	10,495	10,632	0.220	0.131	0.62	15.20	24.79	-0.937	-0.606	0.919
84	78	52	18.424	5.000	2.460	1.952	-0.229	10,924	10,927	0.224	0.132	0.62	14.63	24.46	-1.020	-0.657	1.003

DESIGN DATA - 6'0" DOUBLE BOX, STRAIGHT STRANDS

Span ft.	Depth of Box in.	No. of 1/2"♦ 270k Strands	C.G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.		Maximum Tensile Stress kips per sq. in.		Ultimate Moment ft. kips		Diagonal Tension kips per sq. in.		Area of Stirrups in.^{2}	Required Stirrup Spacing - in.		Deflections - in.		
				Initial Prestress	Final Prestress + All Loads	Initial Prestress	Final Prestress	Required	Provided	1/4 pt.	1/3 pt.		1/4 pt.	1/3 pt.	Beam Wt. + Prestress	Total DL + Prestress	Live Load
26	33	23	2.391	1.359	1.189	-0.330	-0.289	2,174	2,204	0.297	0.212	1.24	19.99	24.75	-0.144	-0.109	0.129
27	33	25	2.816	1.449	1.269	-0.331	-0.289	2,310	2,339	0.304	0.216	1.24	18.69	24.75	-0.163	-0.122	0.148
28	33	27	3.202	1.538	1.346	-0.312	-0.289	2,454	2,470	0.312	0.221	1.24	17.56	24.75	-0.183	-0.136	0.169
29	33	30	3.551	1.682	1.472	-0.340	-0.297	2,607	2,674	0.314	0.222	1.24	16.54	23.88	-0.213	-0.159	0.192
30	33	32	3.854	1.769	1.548	-0.337	-0.295	2,760	2,795	0.320	0.226	1.24	15.72	22.49	-0.236	-0.175	0.217
30	36	28	3.296	1.536	1.344	-0.334	-0.292	2,771	2,829	0.288	0.204	1.24	19.13	27.00	-0.192	-0.142	0.173
31	33	35	4.120	1.911	1.672	-0.345	-0.301	2,914	2,986	0.322	0.226	1.24	14.95	21.24	-0.271	-0.201	0.244
31	36	30	3.651	1.621	1.419	-0.333	-0.292	2,926	2,971	0.293	0.207	1.24	18.17	26.58	-0.213	-0.158	0.195
32	33	37	4.353	1.997	1.748	-0.342	-0.299	3,069	3,073	0.342	0.299	1.24	14.17	19.97	-0.298	-0.220	0.273
32	36	32	3.963	1.707	1.494	-0.333	-0.291	3,081	3,111	0.296	0.209	1.24	17.34	25.17	-0.236	-0.174	0.219
32	39	28	3.415	1.480	1.296	-0.326	-0.285	3,094	3,105	0.271	0.192	1.24	20.85	29.17	-0.192	-0.141	0.178
33	33	40	4.563	2.138	1.871	-0.348	-0.304	3,226	3,273	0.331	0.230	1.24	13.62	19.23	-0.337	-0.248	0.305
33	36	34	4.242	1.792	1.568	-0.332	-0.291	3,239	3,247	0.302	0.211	1.24	16.49	23.93	-0.261	-0.191	0.244
33	39	30	3.779	1.564	1.369	-0.327	-0.286	3,253	3,266	0.276	0.193	1.24	19.72	29.17	-0.213	-0.156	0.199
34	33	42	4.751	2.224	1.946	-0.345	-0.301	3,383	3,387	0.337	0.232	1.24	13.10	18.52	-0.368	-0.269	0.339
34	36	37	4.490	1.929	1.688	-0.341	-0.298	3,398	3,436	0.307	0.212	1.24	15.54	22.50	-0.296	-0.217	0.271
34	39	32	4.102	1.648	1.442	-0.328	-0.287	3,412	3,424	0.280	0.195	1.24	18.77	27.99	-0.236	-0.172	0.221
35	36	37	4.709	2.014	1.763	-0.340	-0.297	3,553	3,580	0.310	0.212	1.24	15.01	21.74	-0.325	-0.237	0.300
35	39	34	4.385	1.732	1.516	-0.329	-0.288	3,569	3,579	0.284	0.196	1.24	17.92	26.72	-0.260	-0.189	0.244
35	42	31	3.930	1.562	1.367	-0.331	-0.290	3,584	3,665	0.260	0.179	1.24	21.13	29.17	-0.221	-0.161	0.202
36	36	41	4.904	2.099	1.837	-0.339	-0.297	3,708	3,716	0.313	0.213	1.24	14.49	21.00	-0.355	-0.257	0.330
36	39	36	4.638	1.815	1.589	-0.330	-0.289	3,724	3,731	0.287	0.196	1.24	17.17	25.56	-0.286	-0.207	0.269
36	42	33	4.251	1.644	1.439	-0.334	-0.292	3,740	3,840	0.263	0.180	1.24	20.17	29.17	-0.244	-0.177	0.223
37	36	44	5.127	2.230	1.952	-0.342	-0.299	3,908	3,912	0.314	0.213	1.24	13.93	19.99	-0.395	-0.287	0.367
37	39	39	4.924	1.944	1.702	-0.336	-0.294	3,925	3,951	0.289	0.197	1.24	16.36	24.06	-0.321	-0.233	0.299
37	42	35	4.613	1.721	1.506	-0.331	-0.290	3,942	4,002	0.266	0.182	1.24	19.26	29.15	-0.267	-0.193	0.248
38	39	41	5.149	2.025	1.773	-0.334	-0.293	4,101	4,101	0.291	0.199	1.24	15.83	23.06	-0.349	-0.252	0.329
38	42	37	4.897	1.830	1.576	-0.331	-0.290	4,119	4,146	0.271	0.186	1.24	18.37	27.43	-0.292	-0.210	0.273
38	45	33	4.536	1.585	1.387	-0.323	-0.282	4,136	4,147	0.251	0.173	1.24	21.60	29.17	-0.242	-0.173	0.229

DESIGN DATA - 6'0" DOUBLE BOX, STRAIGHT STRANDS (Cont.)

Span ft.	Depth of Box in.	No. of 1/2"ϕ 270k Strands	C.G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in. Initial Prestress	Maximum Compressive Stress kips per sq. in. Final Prestress + All Loads	Maximum Tensile Stress kips per sq. in. Initial Prestress	Maximum Tensile Stress kips per sq. in. Final Prestress	Ultimate Moment ft. kips Required	Ultimate Moment ft. kips Provided	Diagonal Tension kips per sq. in. 1/4 pt.	Diagonal Tension kips per sq. in. 1/3 pt.	Area of Stirrups in.^{2}	Required Stirrup Spacing - in. 1/4 pt.	Required Stirrup Spacing - in. 1/3 pt.	Deflections - in. Beam Wt. + Prestress	Deflections - in. Total DL+ Prestress	Deflections - in. Live Load
39	39	44	5.361	2.155	1.886	-0.340	-0.298	4,286	4,326	0.291	0.199	1.24	15.23	22.03	-0.389	-0.281	0.362
39	42	39	5.150	1.880	1.645	-0.332	-0.290	4,293	4,321	0.272	0.186	1.24	17.73	26.29	-0.318	-0.228	0.299
39	45	35	4.867	1.663	1.455	-0.324	-0.283	4,323	4,331	0.254	0.175	1.24	20.66	29.17	-0.264	-0.189	0.252
40	39	47	5.563	2.283	1.998	-0.344	-0.301	4,481	4,532	0.294	0.199	1.24	14.58	21.05	-0.431	-0.311	0.398
40	42	42	5.418	2.004	1.754	-0.337	-0.295	4,501	4,580	0.272	0.185	1.24	17.01	25.16	-0.354	-0.255	0.330
40	45	38	5.181	1.786	1.563	-0.332	-0.291	4,521	4,605	0.255	0.174	1.24	19.60	29.17	-0.297	-0.214	0.277
41	42	44	5.643	2.082	1.822	-0.335	-0.294	4,695	4,733	0.276	0.186	1.24	16.39	24.19	-0.383	-0.274	0.361
41	45	40	5.461	1.862	1.630	-0.332	-0.290	4,716	4,790	0.257	0.174	1.24	18.89	28.60	-0.323	-0.231	0.303
41	48	36	5.184	1.652	1.442	-0.323	-0.283	4,736	4,745	0.245	0.166	1.24	21.59	29.17	-0.270	-0.192	0.257
42	42	47	5.856	2.206	1.931	-0.340	-0.298	4,899	4,963	0.277	0.186	1.24	15.70	23.10	-0.424	-0.304	0.39[illegible]
42	45	43	5.792	1.979	1.732	-0.339	-0.292	4,969	5,059	0.261	0.175	1.24	17.86	26.92	-0.357	-0.251	0.331
42	48	38	5.497	1.727	1.511	-0.324	-0.283	4,936	4,955	0.246	0.166	1.24	20.82	29.17	-0.293	-0.208	0.281
43	42	49	6.045	2.283	1.999	-0.338	-0.296	5,097	5,098	0.281	0.188	1.24	15.14	22.22	-0.456	-0.325	0.43[illegible]
43	45	45	6.021	2.054	1.798	-0.333	-0.291	5,170	5,224	0.264	0.176	1.24	17.22	25.88	-0.385	-0.269	0.36[illegible]
43	48	40	5.788	1.801	1.576	-0.324	-0.283	5,142	5,156	0.248	0.166	1.24	20.04	29.17	-0.318	-0.225	0.307
44	45	47	6.168	2.134	1.868	-0.336	-0.294	5,319	5,392	0.263	0.176	1.24	16.86	25.18	-0.417	-0.296	0.392
44	48	42	6.046	1.875	1.641	-0.324	-0.284	5,343	5,350	0.249	0.167	1.24	19.36	29.17	-0.344	-0.243	0.333
45	45	49	6.366	2.210	1.934	-0.335	-0.293	5,523	5,542	0.266	0.178	1.24	16.27	24.06	-0.447	-0.317	0.425
45	48	45	6.286	1.993	1.744	-0.332	-0.290	5,547	5,643	0.249	0.167	1.24	18.64	28.24	-0.381	-0.270	0.361
46	45	52	6.546	2.330	2.039	-0.341	-0.298	5,725	5,770	0.268	0.179	1.24	15.66	22.94	-0.491	-0.348	0.460
46	48	47	6.504	2.067	1.809	-0.332	-0.290	5,750	5,817	0.251	0.168	1.24	18.02	27.03	-0.410	-0.289	0.391
47	48	49	6.703	2.140	1.873	-0.331	-0.290	5,952	5,984	0.253	0.170	1.24	17.41	25.92	-0.439	-0.309	0.421
48	48	52	6.888	2.257	1.976	-0.338	-0.296	6,154	6,237	0.255	0.170	1.24	16.71	24.76	-0.482	-0.339	0.454
49	48	54	7.068	2.330	2.039	-0.337	-0.295	6,369	6,384	0.259	0.172	1.24	16.11	23.80	-0.514	-0.361	0.489

DESIGN DATA - 7'0" WIDE DOUBLE BOX, STRAIGHT STRANDS

Span ft.	Depth of Box in.	No. of 1/2"φ 270 k Strands	C.G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in. Initial Prestress	Maximum Compressive Stress kips per sq. in. Final Prestress + All Loads	Maximum Tensile Stress kips per sq. in. Initial Prestress	Maximum Tensile Stress kips per sq. in. Final Prestress	Ultimate Moment ft. kips Required	Ultimate Moment ft. kips Provided	Diagonal Tension kips per sq. in. 1/4 pt.	Diagonal Tension kips per sq. in. 1/3 pt.	Area of Stirrups in.²	Required Stirrup Spacing - in. 1/4 pt.	Required Stirrup Spacing - in. 1/3 pt.	Deflections - in. Beam Wt. + Prestress	Deflections - in. Total DL + Prestress	Deflections - in. Live Load
26	33	23	2.250	1.206	1.056	-0.279	-0.244	2,215	2,245	0.311	0.223	1.24	19.94	24.75	-0.124	-0.092	0.113
27	33	25	2.250	1.311	1.148	-0.303	-0.265	2,354	2,423	0.312	0.223	1.24	19.09	24.75	-0.146	-0.108	0.129
28	33	26	2.250	1.364	1.193	-0.315	-0.276	2,501	2,511	0.318	0.227	1.24	18.39	24.75	-0.163	-0.119	0.147
29	33	28	2.387	1.460	1.278	-0.331	-0.290	2,658	2,672	0.321	0.228	1.24	17.59	24.75	-0.186	-0.136	0.167
30	33	31	2.762	1.590	1.392	-0.340	-0.298	2,815	2,888	0.323	0.229	1.24	16.61	24.06	-0.215	-0.157	0.189
30	36	27	2.250	1.367	1.196	-0.318	-0.279	2,826	2,876	0.294	0.209	1.24	20.03	27.00	-0.171	-0.125	0.151
31	33	33	3.090	1.668	1.460	-0.337	-0.295	2,972	3,015	0.330	0.233	1.24	15.81	22.72	-0.237	-0.173	0.213
31	36	29	2.340	1.463	1.281	-0.337	-0.295	2,984	3,061	0.295	0.209	1.24	19.28	27.00	-0.195	-0.142	0.170
32	33	35	3.377	1.746	1.528	-0.335	-0.293	3,130	3,141	0.335	0.237	1.24	15.14	21.60	-0.262	-0.189	0.238
32	36	31	2.726	1.540	1.348	-0.336	-0.294	3,143	3,210	0.299	0.212	1.24	18.35	27.00	-0.216	-0.157	0.191
32	39	28	2.250	1.372	1.200	-0.323	-0.283	3,156	3,262	0.273	0.194	1.24	21.79	29.17	-0.179	-0.131	0.156
33	33	38	3.634	1.874	1.690	-0.342	-0.299	3,291	3,339	0.339	0.237	1.24	14.39	20.54	-0.296	-0.214	0.266
33	36	33	3.070	1.617	1.415	-0.336	-0.294	3,305	3,356	0.306	0.214	1.24	17.41	25.57	-0.238	-0.172	0.213
33	39	29	2.325	1.417	1.240	-0.331	-0.289	3,318	3,361	0.278	0.196	1.24	20.96	29.17	-0.196	-0.141	0.174
34	33	40	3.863	1.952	1.708	-0.339	-0.297	3,453	3,458	0.346	0.240	1.24	13.77	19.67	-0.324	-0.233	0.295
34	36	35	3.375	1.694	1.483	-0.335	-0.293	3,467	3,500	0.311	0.216	1.24	16.59	24.34	-0.262	-0.188	0.237
34	39	31	2.725	1.493	1.307	-0.332	-0.290	3,481	3,529	0.283	0.197	1.24	19.86	29.17	-0.216	-0.156	0.193
35	33	43	4.066	2.078	1.819	-0.345	-0.302	3,612	3,647	0.348	0.239	1.24	13.20	18.86	-0.363	-0.261	0.326
35	36	37	3.644	1.771	1.550	-0.334	-0.293	3,627	3,641	0.316	0.218	1.24	15.88	23.29	-0.287	-0.205	0.262
35	39	33	3.075	1.569	1.373	-0.333	-0.291	3,642	3,695	0.287	0.199	1.24	18.93	28.63	-0.238	-0.171	0.214
35	42	29	2.339	1.373	1.202	-0.324	-0.284	3,657	3,658	0.265	0.184	1.24	22.54	29.17	-0.196	-0.140	0.177
36	33	46	4.246	2.205	1.930	-0.350	-0.306	3,769	3,816	0.353	0.241	1.24	12.62	18.02	-0.404	-0.290	0.350
36	36	40	3.883	1.896	1.659	-0.342	-0.300	3,785	3,865	0.318	0.217	1.24	15.21	22.28	-0.323	-0.231	0.288
36	39	35	3.385	1.645	1.940	-0.334	-0.292	3,801	3,858	0.291	0.200	1.24	18.10	27.21	-0.261	-0.187	0.235
36	42	31	2.735	1.449	1.268	-0.327	-0.287	3,817	3,847	0.327	0.287	1.24	21.45	29.17	-0.216	-0.154	0.195
37	33	49	4.451	2.326	2.036	-0.350	-0.306	3,973	4,001	0.355	0.242	1.24	12.20	17.28	-0.447	-0.320	0.400
37	36	42	4.153	1.968	1.723	-0.337	-0.295	3,989	3,992	0.323	0.221	1.24	14.61	21.18	-0.349	-0.249	0.321
37	39	37	3.734	1.716	1.502	-0.330	-0.289	4,006	4,009	0.296	0.203	1.24	17.31	25.80	-0.284	-0.202	0.262
37	42	34	3.179	1.565	1.370	-0.335	-0.294	4,023	4,133	0.269	0.185	1.24	20.37	29.17	-0.245	-0.175	0.217

DESIGN DATA - 7'0" WIDE DOUBLE BOX, STRAIGHT STRANDS (Cont.)

Span ft.	Depth of Box in.	No. of 1/2"ϕ 270 k Strands	C.G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.		Maximum Tensile Stress kips per sq. in.		Ultimate Moment ft. kips		Diagonal Tension kips per sq. in.		Area of Stirrups in.²	Required Stirrup Spacing - in.		Deflections - in.		
				Initial Prestress	Final Prestress + All Loads	Initial Prestress	Final Prestress	Required	Provided	1/4 pt.	1/3 pt.		1/4 pt.	1/3 pt.	Beam Wt. + Prestress	Total DL+ Prestress	Live Load
38	36	45	4.366	2.090	1.829	-0.342	-0.299	4,169	4,183	0.326	0.223	1.24	13.98	20.07	-0.389	-0.277	0.353
38	39	40	4.008	1.836	1.607	-0.338	-0.296	4,187	4,257	0.296	0.203	1.24	16.62	24.50	-0.319	-0.227	0.288
38	42	36	3.528	1.638	1.433	-0.336	-0.294	4,204	4,308	0.272	0.187	1.24	19.52	29.17	-0.268	-0.191	0.239
38	45	32	2.909	1.446	1.266	-0.327	-0.286	4,222	4,270	0.254	0.175	1.24	22.91	29.17	-0.223	-0.158	0.201
39	36	48	4.566	2.210	1.934	-0.346	-0.303	4,357	4,402	0.326	0.223	1.24	13.53	19.33	-0.430	-0.306	0.388
39	39	42	4.226	1.912	1.673	-0.339	-0.297	4,376	4,412	0.299	0.205	1.24	16.01	23.43	-0.347	-0.246	0.317
39	42	38	3.837	1.710	1.497	-0.336	-0.294	4,384	4,482	0.275	0.189	1.24	18.72	28.14	-0.292	-0.207	0.262
39	45	34	3.316	1.517	1.328	-0.328	-0.287	4,413	4,466	0.257	0.177	1.24	21.85	29.17	-0.244	-0.172	0.221
40	36	51	4.756	2.329	2.038	-0.349	-0.305	4,557	4,604	0.329	0.223	1.24	13.03	18.60	-0.474	-0.337	0.426
40	39	45	4.510	2.026	1.773	-0.341	-0.298	4,576	4,623	0.304	0.207	1.24	15.23	22.22	-0.384	-0.272	0.348
40	42	40	4.162	1.780	1.558	-0.333	-0.291	4,596	4,647	0.280	0.191	1.24	17.90	26.82	-0.316	-0.223	0.289
40	45	36	3.699	1.587	1.389	-0.328	-0.287	4,615	4,657	0.260	0.178	1.24	20.83	29.17	-0.265	-0.187	0.243
41	39	47	4.728	2.098	1.837	-0.338	-0.296	4,774	4,777	0.307	0.208	1.24	14.75	21.49	-0.413	-0.291	0.381
41	42	42	4.435	1.851	1.620	-0.332	-0.290	4,795	4,812	0.283	0.193	1.24	17.21	25.71	-0.341	-0.240	0.316
41	45	38	4.039	1.657	1.450	-0.328	-0.287	4,815	4,846	0.263	0.179	1.24	19.95	29.17	-0.288	-0.202	0.266
41	48	35	3.526	1.512	1.324	-0.328	-0.287	4,836	4,921	0.245	0.167	1.24	23.06	29.17	-0.250	-0.176	0.226
42	39	50	4.933	2.214	1.938	-0.392	-0.299	4,981	5,009	0.308	0.207	1.24	14.22	20.68	-0.455	-0.320	0.417
42	42	45	4.693	1.965	1.720	-0.337	-0.295	5,003	5,057	0.286	0.193	1.24	16.43	24.44	-0.378	-0.266	0.346
42	45	40	4.358	1.726	1.510	-0.327	-0.286	5,024	5,031	0.267	0.181	1.24	19.11	29.17	-0.312	-0.218	0.291
42	48	37	3.907	1.581	1.384	-0.328	-0.287	5,040	5,128	0.248	0.168	1.24	22.06	29.17	-0.271	-0.190	0.247
43	42	47	4.921	2.035	1.782	-0.335	-0.294	5,206	5,228	0.289	0.194	1.24	15.92	23.64	-0.407	-0.285	0.377
43	45	43	4.640	1.838	1.609	-0.334	-0.292	5,228	5,294	0.269	0.181	1.24	18.20	27.68	-0.347	-0.243	0.317
43	48	39	4.261	1.649	1.443	-0.328	-0.287	5,251	5,332	0.251	0.169	1.24	21.11	29.17	-0.294	-0.205	0.270
44	42	50	5.130	2.149	1.881	-0.340	-0.298	5,410	5,487	0.288	0.193	1.24	15.41	22.76	-0.448	-0.313	0.410
44	45	45	4.897	1.907	1.669	-0.333	-0.292	5,433	5,489	0.271	0.182	1.24	17.66	26.70	-0.373	-0.260	0.345
44	48	41	4.574	1.717	1.502	-0.329	-0.288	5,457	5,534	0.253	0.170	1.24	20.32	29.17	-0.317	-0.221	0.293
45	42	52	5.323	2.219	1.942	-0.338	-0.296	5,617	5,638	0.292	0.196	1.24	14.93	21.85	-0.479	-0.334	0.444
45	45	47	5.135	1.976	1.730	-0.332	-0.291	5,642	5,676	0.273	0.183	1.24	17.12	25.64	-0.401	-0.278	0.374
45	48	43	4.864	1.784	1.562	-0.329	-0.288	5,666	5,704	0.257	0.173	1.24	19.44	29.17	-0.342	-0.237	0.318
46	45	49	5.352	4.045	1.790	-0.332	-0.290	5,849	5,856	0.274	0.185	1.24	16.63	24.69	-0.430	-0.297	0.404
46	48	45	5.128	1.852	1.621	-0.329	-0.288	5,874	5,916	0.258	0.174	1.24	18.89	28.71	-0.268	-0.254	0.344

DESIGN DATA - 7'0" WIDE DOUBLE BOX, STRAIGHT STRANDS (Cont.)

Span ft.	Depth of Box in.	No. of 1/2"Φ 270k Strands	C.G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.		Maximum Tensile Stress kips per sq. in.		Ultimate Moment ft. kips		Diagonal Tension kips per sq. in.		Area of Stirrups in.²	Required Stirrup Spacing - in.		Deflections - in.		
				Initial Prestress	Final Prestress + All Loads	Initial Prestress	Final Prestress	Required	Provided	1/4 pt.	1/3 pt.		1/4 pt.	1/3 pt.	Beam Wt. + Prestress	Total DL+ Prestress	Live Load
47	45	52	5.550	2.156	1.887	-0.337	-0.295	6,054	6,129	0.274	0.184	1.24	16.09	23.73	-0.471	-0.326	0.436
47	48	47	5.368	1.920	1.680	-0.329	-0.288	6,080	6,121	0.259	0.175	1.24	18.33	27.67	-0.395	-0.272	0.371
48	48	49	5.591	1.988	1.740	-0.329	-0.288	6,288	6,319	0.262	0.176	1.24	17.74	26.69	-0.423	-0.290	0.399
49	48	52	5.807	2.095	1.834	-0.335	-0.293	6,509	6,616	0.262	0.175	1.24	17.14	25.68	-0.463	-0.318	0.430
50	48	54	6.011	2.161	1.892	-0.334	-0.292	6,734	6,791	0.265	0.176	1.24	16.59	24.79	-0.493	-0.337	0.463

DESIGN DATA - 7'6" WIDE DOUBLE BOX, STRAIGHT STRANDS

Span ft.	Depth of Box in.	No. of 1/2"ϕ 270 k Strands	C.G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.: Initial Prestress	Maximum Compressive Stress kips per sq. in.: Final Prestress + All Loads	Maximum Tensile Stress kips per sq. in.: Initial Prestress	Maximum Tensile Stress kips per sq. in.: Final Prestress	Ultimate Moment ft. kips: Required	Ultimate Moment ft. kips: Provided	Diagonal Tension kips per sq. in.: 1/4 pt.	Diagonal Tension kips per sq. in.: 1/3 pt.	Area of Stirrups in.²	Required Stirrup Spacing - in.: 1/4 pt.	Required Stirrup Spacing - in.: 1/3 pt.	Deflections - in.: Beam Wt. + Prestress	Deflections - in.: Total DL+ Prestress	Deflections - in.: Live Load
26	33	23	2.250	1.139	0.997	-0.256	-0.224	2,247	2,257	0.320	0.230	1.24	19.70	24.79	-0.116	-0.084	0.106
27	33	25	2.250	1.238	1.084	-0.278	-0.243	2,388	2,437	0.322	0.230	1.24	18.87	24.75	-0.136	-0.098	0.121
28	33	27	2.250	1.337	1.171	-0.300	-0.263	2,538	2,615	0.323	0.231	1.24	18.13	24.75	-0.158	-0.115	0.138
29	33	28	2.250	1.387	1.214	-0.311	-0.272	2,697	2,703	0.329	0.234	1.24	17.52	24.75	-0.175	-0.126	0.157
30	33	30	2.271	1.485	1.300	-0.332	-0.291	2,857	2,875	0.330	0.234	1.24	16.91	24.64	-0.201	-0.144	0.177
30	36	27	2.250	1.293	1.131	-0.292	-0.255	2,868	2,893	0.303	0.216	1.24	19.78	27.00	-0.159	-0.144	0.142
31	33	33	2.629	1.608	1.408	-0.340	-0.298	3,017	3,091	0.333	0.235	1.24	16.04	23.16	-0.230	-0.165	0.200
31	36	29	2.250	1.389	1.215	-0.314	-0.274	3,029	3,089	0.303	0.215	1.24	19.13	27.00	-0.183	-0.131	0.160
32	33	35	2.941	1.682	1.473	-0.338	-0.296	3,178	3,220	0.338	0.239	1.24	15.33	21.99	-0.253	-0.181	0.224
32	36	31	2.250	1.484	1.299	-0.335	-0.293	3,191	3,282	0.303	0.214	1.24	18.57	27.00	-0.209	-0.150	0.179
32	39	28	2.250	1.299	1.137	-0.296	-0.259	3,204	3,280	0.286	0.200	1.24	21.49	29.17	-0.167	-0.119	0.147
33	33	37	3.221	1.757	1.537	-0.335	-0.293	3,342	3,345	0.346	0.243	1.24	14.60	20.95	-0.277	-0.196	0.249
33	36	34	2.783	1.594	1.395	-0.334	-0.292	3,355	3,506	0.308	0.216	1.24	17.41	25.66	-0.235	-0.168	0.200
33	39	29	2.250	1.345	1.177	-0.307	-0.268	3,369	3,387	0.286	0.202	1.24	20.75	29.17	-0.183	-0.130	0.164
34	33	40	3.470	1.878	1.643	-0.341	-0.298	3,506	3,546	0.350	0.243	1.24	13.93	19.98	-0.312	-0.221	0.277
34	36	35	2.976	1.629	1.425	-0.331	-0.290	3,520	3,575	0.316	0.220	1.24	16.73	24.65	-0.252	-0.178	0.222
34	39	31	2.250	1.438	1.258	-0.328	-0.287	3,535	3,601	0.287	0.200	1.24	20.04	29.17	-0.209	-0.148	0.182
35	33	43	3.689	1.999	1.749	-0.347	-0.303	3,668	3,741	0.353	0.243	1.24	13.35	19.15	-0.350	-0.248	0.306
35	36	37	3.170	1.708	1.495	-0.337	-0.295	3,683	3,731	0.320	0.221	1.24	16.08	23.70	-0.278	-0.196	0.246
35	39	33	2.488	1.518	1.328	-0.336	-0.294	3,699	3,786	0.289	0.200	1.24	19.21	29.17	-0.232	-0.164	0.201
35	42	30	2.250	1.351	1.182	-0.312	-0.273	3,714	3,803	0.269	0.187	1.24	22.25	29.17	-0.192	-0.135	0.167
36	33	45	3.885	2.073	1.814	-0.344	-0.301	3,829	3,858	0.359	0.245	1.24	12.86	18.45	-0.380	-0.267	0.337
36	36	39	3.430	1.782	1.559	-0.336	-0.294	3,845	3,874	0.325	0.222	1.24	15.43	22.72	-0.303	-0.212	0.271
36	39	35	2.826	1.590	1.392	-0.337	-0.295	3,861	3,952	0.294	0.202	1.24	18.35	27.84	-0.254	-0.179	0.221
36	42	31	2.250	1.396	1.221	-0.322	-0.282	3,877	3,920	0.272	0.188	1.24	21.60	29.17	-0.209	-0.146	0.184
37	33	49	4.106	2.234	1.955	-0.352	-0.308	4,036	4,088	0.363	0.247	1.24	12.24	17.40	-0.430	-0.303	0.376
37	36	42	3.721	1.896	1.659	-0.339	-0.297	4,052	4,092	0.327	0.224	1.24	14.77	21.52	-0.338	-0.236	0.301
37	39	37	3.204	1.658	1.451	-0.333	-0.291	4,069	4,107	0.299	0.205	1.24	17.53	26.26	-0.276	-0.193	0.246
37	42	33	2.538	1.472	1.288	-0.329	-0.288	4,086	4,119	0.275	0.189	1.24	20.71	29.17	-0.231	-0.161	0.205
38	36	45	3.952	2.012	1.761	-0.344	-0.301	4,235	4,308	0.328	0.225	1.24	14.22	20.53	-0.375	-0.263	0.332
38	39	39	3.502	1.728	1.513	-0.332	-0.290	4,253	4,265	0.302	0.208	1.24	16.86	24.98	-0.300	-0.209	0.271
38	42	35	2.917	1.541	1.349	-0.329	-0.288	4,271	4,301	0.278	0.192	1.24	19.83	29.17	-0.252	-0.175	0.225
38	45	32	2.250	1.400	1.226	-0.327	-0.287	4,289	4,366	0.256	0.177	1.24	23.20	29.17	-0.217	-0.152	0.190

DESIGN DATA - 7'6" WIDE DOUBLE BOX, STRAIGHT STRANDS (Cont.)

Span ft.	Depth of Box in.	No. of 1/2"♦ 270 k Strands	C.G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in. Initial Prestress	Maximum Compressive Stress kips per sq. in. Final Prestress + All Loads	Maximum Tensile Stress kips per sq. in. Initial Prestress	Maximum Tensile Stress kips per sq. in. Final Prestress	Ultimate Moment ft. kips Required	Ultimate Moment ft. kips Provided	Diagonal Tension kips per sq. in. 1/4 pt.	Diagonal Tension kips per sq. in. 1/3 pt.	Area of Stirrups in.^{2}	Required Stirrup Spacing - in. 1/4 pt.	Required Stirrup Spacing - in. 1/3 pt.	Deflections - in. Beam Wt. + Prestress	Deflections - in. Total DL+ Prestress	Deflections - in. Live Load
39	36	48	4.169	2.127	1.861	-0.348	-0.304	4,427	4,993	0.334	0.228	1.24	13.57	19.45	-0.415	-0.290	0.365
39	39	42	3.781	1.842	1.612	-0.338	-0.296	4,446	4,514	0.304	0.208	1.24	16.16	23.76	-0.335	-0.233	0.298
39	42	37	3.253	1.611	1.410	-0.330	-0.288	4,453	4,481	0.281	0.194	1.24	18.99	28.74	-0.275	-0.190	0.247
39	45	34	2.622	1.471	1.288	-0.331	-0.290	4,483	4,574	0.259	0.178	1.24	22.17	29.17	-0.238	-0.166	0.208
40	36	50	4.374	2.196	1.922	-0.343	-0.300	4,630	4,631	0.338	0.230	1.24	13.13	18.81	-0.446	-0.310	0.401
40	39	44	4.045	1.884	1.649	-0.309	-0.270	4,649	4,662	0.314	0.215	1.24	15.26	22.33	-0.351	-0.241	0.328
40	42	40	3.604	1.721	1.506	-0.336	-0.294	4,669	4,759	0.283	0.193	1.24	18.11	27.28	-0.307	-0.213	0.272
40	45	36	3.037	1.538	1.346	-0.331	-0.289	3,688	4,768	0.263	0.180	1.24	21.11	29.17	-0.259	-0.179	0.229
41	39	47	4.280	2.023	1.770	-0.340	-0.297	4,851	4,869	0.314	0.213	1.24	14.78	21.61	-0.400	-0.277	0.359
41	42	42	3.900	1.789	1.565	-0.334	-0.292	4,871	4,928	0.287	0.195	1.24	17.40	26.12	-0.331	-0.229	0.298
41	45	38	3.406	1.605	1.404	-0.330	-0.289	4,892	4,961	0.266	0.181	1.24	20.20	29.17	-0.280	-0.194	0.251
41	48	35	2.765	1.468	1.285	-0.331	-0.290	4,912	5,038	0.247	0.169	1.24	23.39	29.17	-0.244	-0.169	0.214
42	39	50	4.502	2.134	1.867	-0.343	-0.300	5,062	5,122	0.314	0.211	1.24	14.31	20.89	-0.440	-0.304	0.392
42	42	44	4.178	1.856	1.624	-0.332	-0.290	5,083	5,094	0.291	0.197	1.24	16.71	25.01	-0.357	-0.245	0.326
42	45	40	3.751	1.671	1.462	-0.329	-0.288	5,105	5,150	0.270	0.183	1.24	19.33	29.17	-0.303	-0.208	0.274
42	48	37	3.198	1.534	1.343	-0.331	-0.290	5,120	5,249	0.250	0.170	1.24	22.35	29.17	-0.265	-0.183	0.233
43	42	47	4.425	1.965	1.720	-0.337	-0.295	5,290	5,330	0.295	0.195	1.24	15.97	23.80	-0.394	-0.271	0.355
43	45	42	4.056	1.737	1.520	-0.329	-0.288	5,312	5,337	0.273	0.184	1.24	18.60	28.51	-0.327	-0.224	0.299
43	48	39	3.581	1.599	1.399	-0.331	-0.290	5,335	5,457	0.253	0.171	1.24	21.38	29.17	-0.286	-0.197	0.255
44	42	49	4.650	2.032	1.779	-0.335	-0.293	5,497	5,507	0.297	0.199	1.24	15.52	23.01	-0.423	-0.289	0.386
44	45	44	4.333	1.804	1.579	-0.328	-0.287	5,521	5,522	0.276	0.186	1.24	17.95	27.30	-0.352	-0.240	0.325
44	48	41	3.920	1.664	1.456	-0.331	-0.290	5,544	5,663	0.256	0.172	1.24	20.56	29.17	-0.309	-0.212	0.277
45	42	52	4.858	2.141	1.874	-0.340	-0.297	5,709	5,776	0.296	0.199	1.24	15.06	22.14	-0.463	-0.317	0.418
45	45	47	4.591	1.910	1.672	-0.334	-0.293	5,733	5,787	0.278	0.187	1.24	17.18	25.83	-0.389	-0.265	0.352
45	48	43	4.234	1.729	1.513	-0.331	-0.290	5,758	5,866	0.258	0.174	1.24	19.81	29.17	-0.333	-0.227	0.300
46	45	49	4.825	1.976	1.730	-0.333	-0.292	5,944	5,981	0.279	0.188	1.24	16.72	24.93	-0.417	-0.283	0.381
46	48	45	4.518	1.794	1.570	-0.331	-0.290	5,969	6,022	0.263	0.178	1.24	18.92	28.87	-0.358	-0.243	0.325
47	45	51	5.038	2.043	1.788	-0.332	-0.291	6,153	6,168	0.281	0.189	1.24	16.25	24.09	-0.446	-0.301	0.411
47	48	47	4.777	1.859	1.627	-0.331	-0.290	6,180	6,242	0.264	0.178	1.24	18.40	27.89	-0.384	-0.259	0.350
48	48	[illegible]	5.018	1.923	1.683	-0.331	-0.290	6,392	6,453	0.266	0.179	1.24	17.85	26.97	-0.411	-0.276	0.377
49	48	51	5.251	1.988	1.740	-0.330	-0.289	6,616	6,655	0.268	0.180	1.24	17.31	26.07	-0.438	-0.293	0.406
50	48	53	5.470	2.051	1.795	-0.329	-0.288	6,846	6,849	0.271	0.180	1.24	16.80	25.23	-0.467	-0.311	0.437

DESIGN DATA--3'0" WIDE SINGLE BOX, STRAIGHT STRANDS, NO TENSION

Span ft.	Depth of Box in.	No. of 1/2"ϕ 270 k Strands	C. G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.		Ultimate Moment ft. kips		Diagonal Tension kips per sq. in.		Area of Stirrups $in.^2$	Required Stirrup Spacing - in.		Deflections - in.		
				Initial Prestress	Final Prestress + All Loads	Required	Provided	1/4 pt.	1/3 pt.		1/4 pt.	1/3 pt.	Beam Wt. + Prestress	Total DL + Prestress	Live Load
26	33	16	8.226	1.357	1.188	1,092	1,159	0.297	0.208	0.62	14.80	21.65	-0.111	-0.079	0.127
27	33	17	8.226	1.442	1.262	1,160	1,219	0.301	0.210	0.62	14.17	20.56	-0.126	-0.090	0.145
28	33	18	8.226	1.527	1.336	1,233	1,278	0.304	0.212	0.62	13.61	19.59	-0.144	-0.102	0.166
29	33	19	8.226	1.611	1.410	1,310	1,326	0.310	0.217	0.62	12.98	18.54	-0.162	-0.114	0.189
29	36	17	8.921	1.377	1.205	1,316	1,352	0.285	0.200	0.62	15.32	22.47	-0.125	-0.087	0.151
30	33	21	8.226	1.781	1.559	1,387	1,446	0.304	0.211	0.62	12.57	17.86	-0.193	-0.137	0.214
30	36	18	8.921	1.458	1.276	1,394	1,418	0.287	0.200	0.62	14.78	21.52	-0.142	-0.099	0.170
31	33	22	8.226	1.866	1.633	1,465	1,502	0.306	0.212	0.62	12.19	17.24	-0.215	-0.152	0.240
31	36	20	8.921	1.620	1.418	1,472	1,545	0.283	0.197	0.62	14.15	20.45	-0.170	-0.119	0.192
32	33	23	8.226	1.951	1.707	1,542	1,555	0.308	0.213	0.62	11.84	16.67	-0.239	-0.168	0.269
32	36	21	8.921	1.701	1.488	1,550	1,610	0.283	0.196	0.62	13.77	19.81	-0.189	-0.133	0.215
32	39	19	9.639	1.472	1.288	1,557	1,624	0.267	0.186	0.62	15.79	23.23	-0.149	-0.104	0.174
33	33	25	8.226	2.120	1.756	1,621	1,652	0.308	0.211	0.62	11.32	15.96	-0.277	-0.197	0.300
33	36	22	8.921	1.782	1.559	1,629	1,673	0.286	0.196	0.62	13.30	19.17	-0.210	-0.147	0.240
33	39	20	9.639	1.550	1.356	1,637	1,700	0.268	0.185	0.62	15.28	22.52	-0.166	-0.115	0.195
34	33	27	8.226	2.290	2.004	1,701	1,739	0.310	0.210	0.62	10.80	15.24	-0.319	-0.227	0.334
34	36	23	8.921	1.863	1.630	1,709	1,733	0.289	0.197	0.62	12.86	18.56	-0.232	-0.162	0.266
34	39	21	9.639	1.627	1.424	1,717	1,773	0.270	0.184	0.62	14.79	21.84	-0.185	-0.128	0.216
35	36	25	8.921	2.025	1.772	1,788	1,844	0.288	0.194	0.62	12.34	17.82	-0.269	-0.189	0.294
35	39	22	9.639	1.705	1.492	1,797	1,843	0.271	0.184	0.62	14.35	21.21	-0.205	-0.141	0.239
35	42	20	10.377	1.485	1.300	1,805	1,854	0.257	0.175	0.62	16.33	24.72	-0.163	-0.111	0.198
36	36	26	8.921	2.106	1.843	1,865	1,896	0.291	0.195	0.62	11.94	17.25	-0.295	-0.206	0.324
36	39	23	9.639	1.782	1.560	1,875	1,910	0.273	0.183	0.62	13.91	20.57	-0.226	-0.155	0.263
36	42	21	10.377	1.560	1.365	1,884	1,935	0.258	0.174	0.62	15.86	24.02	-0.181	-0.123	0.217
37	36	28	8.921	2.268	1.985	1,966	1,995	0.291	0.195	0.62	11.47	16.41	-0.337	-0.237	0.361
37	39	25	9.639	1.937	1.695	1,976	2,035	0.271	0.182	0.62	13.37	19.56	-0.262	-0.181	0.293
37	42	22	10.377	1.634	1.430	1,986	2,012	0.258	0.175	0.62	15.40	23.09	-0.200	-0.135	0.242
38	39	26	9.639	2.015	1.763	2,065	2,094	0.273	0.184	0.62	12.98	18.83	-0.286	-0.197	0.323
38	42	24	10.377	1.782	1.560	2,075	2,157	0.254	0.172	0.62	14.86	22.05	-0.232	-0.159	0.266
38	45	22	11.133	1.569	1.373	2,086	2,180	0.242	0.164	0.62	16.86	24.79	-0.188	-0.127	0.223

DESIGN DATA--3'0" WIDE SINGLE BOX, STRAIGHT STRANDS, NO TENSION (cont.)

Span ft.	Depth of Box in.	No. of 1/2"ϕ 270 k Strands	C. G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.		Ultimate Moment ft. kips		Diagonal Tension kips per sq. in.		Area of Stirrups in.²	Required Stirrup Spacing - in.		Deflections - in.		
				Initial Prestress	Final Prestress + All Loads	Required	Provided	1/4 pt.	1/3 pt.		1/4 pt.	1/3 pt.	Beam Wt. + Prestress	Total DL + Prestress	Live Load
39	39	28	9.639	2.170	1.899	2,158	2,202	0.273	0.184	0.62	12.43	17.90	-0.326	-0.226	0.355
39	42	25	10.377	1.857	1.625	2,192	2,225	0.263	0.178	0.62	14.20	20.84	-0.254	-0.172	0.296
39	45	23	11.133	1.640	1.436	2,180	2,261	0.243	0.164	0.62	16.35	24.66	-0.206	-0.139	0.245
40	42	26	10.377	1.931	1.690	2,268	2,290	0.260	0.174	0.62	13.91	20.47	-0.277	-0.188	0.322
40	45	24	11.133	1.712	1.498	2,280	2,339	0.245	0.165	0.62	15.80	23.80	-0.226	-0.152	0.270
41	42	28	10.377	2.080	1.820	2,366	2,413	0.261	0.174	0.62	13.32	19.55	-0.316	-0.216	0.353
41	45	25	11.133	1.783	1.560	2,378	2,414	0.248	0.166	0.62	15.31	23.01	-0.247	-0.165	0.295
41	48	24	11.906	1.646	1.441	2,383	2,520	0.231	0.155	0.62	17.22	24.79	-0.213	-0.143	0.249
42	42	30	10.377	2.228	1.950	2,469	2,503	0.271	0.180	0.62	12.57	18.35	-0.357	-0.246	0.386
42	45	27	11.133	1.926	1.685	2,478	2,556	0.247	0.164	0.62	14.69	21.99	-0.282	-0.191	0.382
42	48	25	11.906	1.715	1.501	2,494	2,602	0.233	0.155	0.62	16.55	24.79	-0.232	-0.155	0.274
43	45	28	11.133	1.997	1.748	2,579	2,622	0.251	0.166	0.62	14.22	21.26	-0.306	-0.206	0.351
43	48	25	11.906	1.715	1.501	2,595	2,602	0.233	0.155	0.62	16.19	24.79	-0.240	-0.158	0.298
44	45	30	11.133	2.140	1.873	2,681	2,747	0.252	0.166	0.62	13.62	20.21	-0.345	-0.235	0.382
44	48	27	11.906	1.852	1.621	2,697	2,757	0.238	0.157	0.62	15.57	23.66	-0.274	-0.182	0.324
45	48	28	11.906	1.920	1.681	2,800	2,831	0.240	0.159	0.62	15.10	22.72	-0.296	-0.197	0.351
46	48	30	11.906	2.058	1.801	2,903	2,969	0.240	0.159	0.62	14.50	21.60	-0.334	-0.224	0.380
46	54	26	13.416	1.607	1.406	2,946	3,089	0.219	0.146	0.62	18.35	24.79	-0.223	-0.145	0.271
47	48	31	11.906	2.126	1.861	3,004	3,045	0.242	0.101	0.62	14.15	20.96	-0.359	-0.240	0.410
48	54	28	13.416	1.731	1.515	3,154	3,274	0.222	0.147	0.62	17.30	24.79	-0.260	-0.169	0.314
50	54	30	13.416	1.854	1.623	3,377	3,448	0.225	0.148	0.62	16.30	24.79	-0.301	-0.194	0.364
52	54	32	13.416	1.978	1.731	3,605	3,609	0.229	0.150	0.62	15.41	23.49	-0.346	-0.221	0.420
54	60	31	15.020	1.792	1.569	3,879	3,988	0.211	0.138	0.62	17.74	24.79	-0.296	-0.186	0.367
56	60	33	15.020	1.908	1.670	4,127	4,171	0.215	0.140	0.62	16.74	24.79	-0.337	-0.210	0.419
58	60	36	15.020	2.082	1.822	4,378	4,426	0.218	0.141	0.62	15.68	24.13	-0.397	-0.250	0.476
60	66	35	16.670	1.901	1.664	4,690	4,851	0.202	0.130	0.62	17.84	24.79	-0.342	-0.211	0.422
62	66	37	16.670	2.010	1.759	4,959	5,038	0.205	0.133	0.62	16.96	24.79	-0.385	-0.236	0.475
64	72	37	18.357	1.895	1.658	5,287	5,571	0.190	0.123	0.62	18.98	24.79	-0.347	-0.211	0.426
66	72	39	18.357	1.997	1.748	5,599	5,795	0.192	0.124	0.62	18.15	24.79	-0.388	-0.234	0.480
68	78	39	20.076	1.889	1.654	5,931	6,331	0.181	0.117	0.62	19.97	24.79	-0.351	-0.210	0.434
70	78	40	20.076	1.938	1.696	6,223	6,441	0.185	0.119	0.62	19.26	24.79	-0.376	-0.219	0.481
72	78	42	20.076	2.035	1.781	6,517	6,529	0.193	0.124	0.62	17.87	24.79	-0.416	-0.241	0.532

DESIGN DATA--4'0" WIDE SINGLE BOX, STRAIGHT STRANDS, NO TENSION

Span ft.	Depth of Box in.	No. of 1/2"ϕ 270 k Strands	C. G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in. Initial Prestress	Maximum Compressive Stress kips per sq. in. Final Prestress + All Loads	Ultimate Moment ft. kips Required	Ultimate Moment ft. kips Provided	Diagonal Tension kips per sq. in. 1/4 pt.	Diagonal Tension kips per sq. in. 1/3 pt.	Area of Stirrups in.²	Required Stirrup Spacing - in. 1/4 pt.	Required Stirrup Spacing - in. 1/3 pt.	Deflections - in. Beam Wt. + Prestress	Deflections - in. Total DL + Prestress	Deflections - in. Live Load
26	33	20	7.65	1.404	1.229	1,442	1,503	0.422	0.301	0.62	10.29	14.33	-0.116	-0.084	0.131
27	33	21	7.65	1.474	1.290	1,532	1,566	0.429	0.307	0.62	9.92	13.74	-0.131	-0.094	0.150
28	33	22	7.65	1.544	1.352	1,628	1,629	0.436	0.312	0.62	9.58	13.21	-0.147	-0.105	0.171
29	33	24	7.65	1.685	1.475	1,729	1,750	0.437	0.311	0.62	9.23	12.67	-0.173	-0.123	0.195
29	36	21	8.26	1.418	1.242	1,735	1,737	0.405	0.289	0.62	10.66				
30	33	26	7.65	1.825	1.597	1,831	1,856	0.441	0.313	0.62	8.84	12.07	-0.201	-0.144	0.220
30	36	23	8.26	1.554	1.360	1,837	1,877	0.403	0.287	0.62	10.29	14.27	-0.155	-0.110	0.176
31	33	28	7.65	1.966	1.720	1,933	1,982	0.438	0.309	0.62	8.63	11.75	-0.232	-0.166	0.248
31	36	24	8.26	1.621	1.419	1,940	1,945	0.408	0.290	0.62	10.00	13.82	-0.172	-0.121	0.199
32	33	29	7.65	2.036	1.782	2,035	2,041	0.442	0.312	0.62	8.44	11.45	-0.255	-0.181	0.278
32	36	26	8.26	1.756	1.537	2,043	2,069	0.409	0.289	0.62	9.64	13.26	-0.199	-0.141	0.222
32	39	23	8.895	1.497	1.310	2,050	2,062	0.380	0.270	0.62	11.07	15.64	-0.154	-0.108	0.182
33	36	28	8.26	1.891	1.656	2,147	2,209	0.407	0.285	0.62	9.37	12.93	-0.229	-0.162	0.248
33	39	25	8.895	1.627	1.424	2,155	2,197	0.384	0.270	0.62	10.57	14.77	-0.179	-0.126	0.203
34	36	29	8.26	1.959	1.715	2,252	2,275	0.412	0.286	0.62	9.12	12.62	-0.251	-0.177	0.276
34	39	26	8.895	1.693	1.481	2,261	2,279	0.387	0.270	0.62	10.31	14.46	-0.197	-0.138	0.225
35	39	28	8.895	1.823	1.595	2,364	2,435	0.383	0.264	0.62	10.06	14.14	-0.226	-0.158	0.249
35	42	25	9.550	1.570	1.374	2,373	2,398	0.365	0.254	0.62	11.25	16.03	-0.178	-0.123	0.206
36	39	29	8.895	1.888	1.652	2,467	2,508	0.387	0.265	0.62	9.81	13.83	-0.247	-0.172	0.274
36	42	26	9.550	1.633	1.429	2,476	2,488	0.367	0.253	0.62	11.00	15.72	-0.195	-0.134	0.227
37	39	31	8.895	2.018	1.766	2,600	2,646	0.386	0.265	0.62	9.53	13.33	-0.279	-0.195	0.305
37	42	28	9.550	1.759	1.539	2,610	2,658	0.363	0.250	0.62	10.74	15.24	-0.223	-0.154	0.253
38	42	29	9.550	1.822	1.594	2,727	2,739	0.365	0.252	0.62	10.51	14.82	-0.243	-0.167	0.279
38	45	27	10.227	1.639	1.434	2,738	2,789	0.343	0.238	0.62	11.69	16.70	-0.202	-0.138	0.234
39	42	31	9.550	1.947	1.704	2,850	2,892	0.364	0.250	0.62	10.20	14.32	-0.274	-0.189	0.306
39	45	28	10.227	1.699	1.487	2,861	2,880	0.346	0.239	0.62	11.42	16.25	-0.220	-0.150	0.258
40	42	33	9.550	2.073	1.814	2,980	3,033	0.366	0.250	0.62	9.86	13.83	-0.308	-0.214	0.337
40	45	30	10.227	1.821	1.594	2,992	3,053	0.344	0.236	0.62	11.08	15.77	-0.249	-0.171	0.283

DESIGN DATA--4'0" WIDE SINGLE BOX, STRAIGHT STRANDS, NO TENSION (cont.)

Span ft.	Depth of Box in.	No. of 1/2" ϕ 270 k Strands	C. G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.: Initial Prestress	Maximum Compressive Stress kips per sq. in.: Final Prestress + All Loads	Ultimate Moment ft. kips: Required	Ultimate Moment ft. kips: Provided	Diagonal Tension kips per sq. in.: 1/4 pt.	Diagonal Tension kips per sq. in.: 1/3 pt.	Area of Stirrups in.²	Required Stirrup Spacing - in.: 1/4 pt.	Required Stirrup Spacing - in.: 1/3 pt.	Deflections - in.: Beam Wt. + Prestress	Deflections - in.: Total DL + Prestress	Deflections - in.: Live Load
41	45	31	10.227	1.881	1.647	3,121	3,136	0.348	0.237	0.62	10.80	15.38	-0.269	-0.183	0.310
41	48	29	10.922	1.702	1.490	3,133	3,196	0.328	0.224	0.62	11.96	17.27	-0.226	-0.153	0.264
42	45	33	10.227	2.003	1.753	3,256	3,291	0.349	0.237	0.62	10.44	14.85	-0.302	-0.207	0.339
42	48	30	10.922	1.761	1.541	3,269	3,288	0.332	0.226	0.62	11.65	16.82	-0.245	-0.165	0.288
43	45	35	10.227	2.124	1.859	3,388	3,436	0.351	0.236	0.62	10.10	14.35	-0.337	-0.231	0.369
43	48	32	10.922	1.879	1.644	3,401	3,465	0.331	0.223	0.62	11.31	16.31	-0.275	-0.187	0.314
44	48	33	10.922	1.937	1.696	3,534	3,548	0.334	0.226	0.62	11.03	15.86	-0.296	-0.200	0.341
45	48	35	10.922	2.055	1.798	3,669	3,707	0.335	0.226	0.62	10.69	15.24	-0.330	-0.224	0.370
46	54	32	12.668	1.629	1.426	3,873	3,937	0.278	0.188	0.62	13.06	19.42	-0.231	-0.151	0.282
48	54	35	12.668	1.782	1.560	4,146	4,237	0.279	0.188	0.62	12.38	18.27	-0.275	-0.180	0.327
50	54	38	12.668	1.935	1.694	4,439	4,513	0.282	0.188	0.62	11.70	17.20	-0.324	-0.213	0.379
52	54	41	12.668	2.088	1.827	4,738	4,766	0.286	0.190	0.62	11.08	16.21	-0.378	-0.248	0.436
54	60	37	14.178	1.809	1.636	5,089	5,190	0.264	0.175	0.62	12.70	18.99	-0.319	-0.204	0.383
56	60	42	14.178	2.013	1.762	5,414	5,477	0.268	0.177	0.62	12.00	17.83	-0.370	-0.237	0.438
58	60	45	14.178	2.157	1.888	5,742	5,772	0.271	0.177	0.62	11.44	16.92	-0.425	-0.272	0.497
60	66	43	15.740	1.946	1.703	6,140	6,208	0.253	0.166	0.62	12.89	19.49	-0.362	-0.226	0.443
62	66	46	15.740	2.082	1.822	6,492	6,503	0.256	0.168	0.62	12.26	18.27	-0.414	-0.259	0.499
64	72	45	17.345	1.930	1.689	6,909	7,072	0.238	0.157	0.62	13.71	20.76	-0.366	-0.224	0.450
66	72	48	17.345	2.058	1.802	7,317	7,393	0.242	0.159	0.62	13.03	19.55	-0.415	-0.255	0.507
68	78	47	18.988	1.915	1.676	7,737	7,977	0.227	0.149	0.62	14.42	22.10	-0.368	-0.222	0.459
70	78	50	18.988	2.037	1.783	8,116	8,323	0.229	0.150	0.62	13.77	20.92	-0.416	-0.251	0.510

DESIGN DATA--6'0" WIDE DOUBLE BOX, STRAIGHT STRANDS, NO TENSION

Span ft.	Depth of Box in.	No. of 1/2"ϕ 270 k Strands	C. G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.		Ultimate Moment ft. kips		Diagonal Tension kips per sq. in.		Area of Stirrups in.²	Required Stirrup Spacing - in.		Deflections - in.		
				Initial Prestress	Final Prestress + All Loads	Required	Provided	1/4 pt.	1/3 pt.		1/4 pt.	1/3 pt.	Beam Wt. + Prestress	Total DL + Prestress	Live Load
26	33	30	7.906	1.342	1.174	2,174	2,228	0.367	0.261	1.24	14.14	20.06	-0.110	-0.078	0.129
27	33	32	7.906	1.431	1.253	2,310	2,353	0.371	0.263	1.24	13.58	19.14	-0.126	-0.090	0.148
28	33	34	7.906	1.521	1.331	2,454	2,475	0.376	0.266	1.24	13.08	18.32	-0.144	-0.102	0.169
29	33	37	7.906	1.655	1.449	2,607	2,653	0.376	0.265	1.24	12.58	17.52	-0.169	-0.120	0.192
30	33	40	7.906	1.789	1.566	2,760	2,817	0.378	0.266	1.24	12.08	16.74	-0.196	-0.139	0.217
30	36	35	8.551	1.502	1.315	2,771	2,815	0.349	0.247	1.24	14.10	19.90	-0.148	-0.104	0.173
31	33	42	7.906	1.879	1.644	2,914	2,938	0.379	0.266	1.24	11.76	16.26	-0.219	-0.155	0.244
31	36	37	8.551	1.588	1.390	2,926	2,949	0.351	0.248	1.24	13.66	19.20	-0.167	-0.117	0.195
32	33	45	7.906	2.013	1.762	3,069	3,106	0.377	0.264	1.24	11.44	15.74	-0.250	-0.178	0.273
32	36	40	8.551	1.717	1.502	3,081	3,138	0.350	0.246	1.24	13.20	18.46	-0.193	-0.136	0.219
32	39	36	9.219	1.484	1.299	3,094	3,168	0.326	0.230	1.24	15.16	21.58	-0.152	-0.106	0.178
33	33	48	7.906	2.147	1.879	3,226	3,261	0.380	0.263	1.24	11.02	15.20	-0.284	-0.202	0.305
33	36	42	8.551	1.802	1.578	3,239	3,273	0.353	0.246	1.24	12.80	17.96	-0.215	-0.151	0.244
33	39	38	9.219	1.567	1.371	3,253	3,299	0.332	0.232	1.24	14.52	20.72	-0.170	-0.118	0.199
34	33	51	7.906	2.282	1.997	3,383	3,402	0.385	0.264	1.24	10.60	14.66	-0.320	-0.228	0.339
34	36	44	8.551	1.888	1.653	3,398	3,402	0.356	0.246	1.24	12.42	17.46	-0.238	-0.166	0.271
34	39	40	9.219	1.649	1.444	3,412	3,456	0.332	0.230	1.24	14.14	20.22	-0.190	-0.132	0.221
35	36	47	8.551	2.017	1.765	3,553	3,582	0.356	0.243	1.24	12.02	16.94	-0.270	-0.189	0.300
35	39	42	9.219	1.732	1.516	3,569	3,606	0.333	0.229	1.24	13.76	19.72	-0.211	-0.146	0.244
35	42	38	9.909	1.508	1.320	3,584	3,599	0.317	0.218	1.24	15.48	22.56	-0.168	-0.115	0.202
36	36	50	8.551	2.146	1.878	3,708	3,749	0.358	0.243	1.24	11.60	16.38	-0.305	-0.214	0.330
36	39	44	9.219	1.814	1.588	3,724	3,749	0.335	0.228	1.24	13.40	19.22	-0.234	-0.161	0.269
36	42	40	9.909	1.587	1.389	3,740	3,771	0.316	0.216	1.24	15.11	22.06	-0.187	-0.128	0.223
37	36	54	8.551	2.318	2.028	3,908	3,949	0.360	0.244	1.24	11.14	15.58	-0.349	-0.246	0.367
37	39	47	9.219	1.938	1.696	3,925	3,951	0.334	0.228	1.24	12.98	18.48	-0.264	-0.183	0.299
37	42	43	9.909	1.706	1.494	3,942	4,016	0.313	0.214	1.24	14.70	21.24	-0.213	-0.146	0.248
38	39	50	9.219	2.062	1.805	4,101	4,139	0.334	0.228	1.24	12.58	17.76	-0.297	-0.206	0.32[illegible]
38	42	45	9.909	1.786	1.563	4,119	4,171	0.314	0.215	1.24	14.34	20.60	-0.235	-0.161	0.273
38	45	41	10.619	1.568	1.372	4,136	4,175	0.299	0.205	1.24	16.08	23.50	-0.190	-0.128	0.229

DESIGN DATA--6'0" WIDE DOUBLE BOX, STRAIGHT STRANDS, NO TENSION (cont.)

Span ft.	Depth of Box in.	No. of 1/2"♦ 270 k Strands	C. G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.		Ultimate Moment ft. kips		Diagonal Tension kips per sq. in.		Area of Stirrups in.²	Required Stirrup Spacing - in.		Deflections - in.		
				Initial Prestress	Final Prestress + All Loads	Required	Provided	1/4 pt.	1/3 pt.		1/4 pt.	1/3 pt.	Beam Wt. + Prestress	Total DL + Prestress	Live Load
39	39	53	9.219	2.186	1.913	4,286	4,311	0.337	0.229	1.24	12.14	17.06	-0.332	-0.231	0.362
39	42	47	9.909	1.865	1.632	4,293	4,318	0.316	0.216	1.24	13.92	19.92	-0.258	-0.176	0.299
39	45	43	10.619	1.644	1.439	4,323	4,351	0.299	0.205	1.24	15.66	22.78	-0.209	-0.141	0.252
40	42	50	9.909	1.984	1.737	4,501	4,526	0.317	0.215	1.24	13.44	19.20	-0.290	-0.199	0.330
40	45	46	10.619	1.759	1.540	4,521	4,602	0.298	0.203	1.24	15.14	22.02	-0.237	-0.161	0.277
41	42	53	9.909	2.103	1.841	4,695	4,720	0.319	0.215	1.24	12.96	18.52	-0.324	-0.222	0.361
41	45	48	10.619	1.836	1.607	4,716	4,760	0.300	0.203	1.24	14.70	21.38	-0.259	-0.175	0.303
41	48	44	11.347	1.624	1.421	4,736	4,777	0.286	0.194	1.24	16.44	24.32	-0.212	-0.141	0.257
42	42	56	9.909	2.222	1.945	4,899	4,899	0.323	0.216	1.24	12.48	17.80	-0.359	-0.247	0.395
42	45	51	10.619	1.951	1.707	4,920	4,985	0.302	0.203	1.24	14.18	20.58	-0.290	-0.197	0.331
42	48	46	11.347	1.698	1.486	4,936	4,957	0.287	0.194	1.24	15.98	24.62	-0.232	-0.155	0.281
43	45	53	10.619	2.027	1.774	5,120	5,126	0.305	0.204	1.24	13.78	19.98	-0.315	-0.214	0.361
43	48	49	11.347	1.808	1.583	5,142	5,213	0.287	0.192	1.24	15.46	22.80	-0.260	-0.174	0.307
44	45	56	10.619	2.142	1.875	5,319	5,326	0.306	0.204	1.24	13.32	19.20	-0.350	-0.238	0.392
44	48	51	11.347	1.882	1.647	5,343	5,375	0.289	0.193	1.24	15.04	22.06	-0.283	-0.189	0.333
45	48	54	11.347	1.993	1.744	5,547	5,606	0.290	0.194	1.24	14.54	21.16	-0.315	-0.212	0.361
46	48	56	11.347	2.067	1.809	5,750	5,751	0.292	0.196	1.24	14.14	20.44	-0.340	-0.228	0.391
47	45	59	11.347	2.178	1.906	5,952	5,957	0.294	0.197	1.24	13.66	19.62	-0.375	-0.252	0.421

DESIGN DATA--7'0" WIDE DOUBLE BOX, STRAIGHT STRANDS, NO TENSION

Span ft.	Depth of Box in.	No. of 1/2"ϕ 270k Strands	C. G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.		Ultimate Moment ft. kips		Diagonal Tension kips per sq. in.		Area of Stirrups in.²	Required Stirrup Spacing - in.		Deflections - in.		
				Initial Prestress	Final Prestress + All Loads	Required	Provided	1/4 pt.	1/3 pt.		1/4 pt.	1/3 pt.	Beam Wt. + Prestress	Total DL + Prestress	Live Load
26	33	29	7.607	1.169	1.023	2,215	2,240	0.382	0.273	1.24	14.40	20.55	-0.094	-0.065	0.113
27	33	31	7.607	1.249	1.094	2,354	2,374	0.387	0.276	1.24	13.84	19.61	-0.108	-0.074	0.129
28	33	33	7.607	1.330	1.164	2,501	2,506	0.391	0.279	1.24	13.33	18.78	-0.123	-0.085	0.147
29	33	36	7.607	1.451	1.270	2,658	2,699	0.391	0.278	1.24	12.83	17.99	-0.145	-0.100	0.167
30	33	38	7.607	1.532	1.341	2,815	2,825	0.395	0.280	1.24	12.43	17.34	-0.163	-0.112	0.189
30	36	34	8.207	1.320	1.155	2,826	2,849	0.364	0.259	1.24	14.36	20.41	-0.128	-0.087	0.151
31	33	41	7.607	1.653	1.446	2,972	3,010	0.395	0.279	1.24	12.03	16.71	-0.189	-0.130	0.213
31	36	36	8.207	1.398	1.223	2,984	2,994	0.366	0.260	1.24	13.93	19.69	-0.144	-0.098	0.170
32	33	44	7.607	1.774	1.552	3,130	3,154	0.401	0.282	1.24	11.49	15.88	-0.216	-0.149	0.238
32	36	39	8.207	1.514	1.325	3,143	3,206	0.364	0.257	1.24	13.50	19.01	-0.167	-0.114	0.191
32	39	35	8.830	1.310	1.147	3,156	3,206	0.340	0.241	1.24	15.44	22.13	-0.131	-0.089	0.156
33	33	47	7.607	1.895	1.658	3,291	3,352	0.399	0.278	1.24	11.21	15.55	-0.246	-0.170	0.266
33	36	41	8.207	1.592	1.393	3,305	3,344	0.368	0.258	1.24	13.06	18.43	-0.186	-0.127	0.213
33	39	37	8.830	1.385	1.213	3,318	3,365	0.343	0.241	1.24	14.92	21.43	-0.148	-0.099	0.174
34	33	49	7.607	1.975	1.729	3,453	3,476	0.402	0.278	1.24	10.92	15.20	-0.271	-0.187	0.295
34	36	43	8.207	1.669	1.461	3,467	3,480	0.372	0.258	1.24	12.66	17.91	-0.207	-0.140	0.237
34	39	39	8.830	1.460	1.278	3,481	3,522	0.345	0.241	1.24	14.44	20.79	-0.185	-0.111	0.193
35	36	46	8.207	1.786	1.563	3,627	3,665	0.374	0.257	1.24	12.20	17.28	-0.235	-0.160	0.262
35	39	41	8.830	1.535	1.344	3,642	3,676	0.347	0.240	1.24	14.03	20.23	-0.184	-0.123	0.214
35	42	37	9.475	1.338	1.171	3,657	3,663	0.328	0.227	1.24	15.87	23.31	-0.146	-0.096	0.177
36	36	48	8.207	1.864	1.631	3,785	3,807	0.375	0.256	1.24	11.93	16.93	-0.259	-0.175	0.288
36	39	44	8.830	1.648	1.442	3,801	3,874	0.350	0.240	1.24	13.46	19.40	-0.209	-0.141	0.235
36	42	39	9.475	1.410	1.234	3,817	3,835	0.329	0.226	1.24	15.42	22.66	-0.163	-0.107	0.195
37	36	51	8.207	1.980	1.733	3,989	4,008	0.374	0.255	1.24	11.63	16.39	-0.291	-0.197	0.321
37	39	46	8.830	1.722	1.508	4,006	4,038	0.350	0.240	1.24	13.19	18.88	-0.230	-0.155	0.262
37	42	42	9.475	1.519	1.329	4,023	4,089	0.327	0.225	1.24	14.96	21.80	-0.186	-0.124	0.217
38	39	48	8.830	1.797	1.573	4,187	4,196	0.350	0.240	1.24	12.92	18.38	-0.253	-0.169	0.288
38	42	44	9.475	1.591	1.393	4,204	4,229	0.331	0.228	1.24	14.46	20.89	-0.206	-0.136	0.239
38	45	40	10.141	1.398	1.224	4,222	4,239	0.311	0.215	1.24	16.37	24.10	-0.166	-0.108	0.201

DESIGN DATA--7'0" WIDE DOUBLE BOX, STRAIGHT STRANDS, NO TENSION (cont.)

Span ft.	Depth of Box in.	No. of 1/2"♦ 270k Strands	C. G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in. Initial Prestress	Maximum Compressive Stress kips per sq. in. Final Prestress + All Loads	Ultimate Moment ft. kips Required	Ultimate Moment ft. kips Provided	Diagonal Tension kips per sq. in. 1/4 pt.	Diagonal Tension kips per sq. in. 1/3 pt.	Area of Stirrups $in.^2$	Required Stirrup Spacing - in. 1/4 pt.	Required Stirrup Spacing - in. 1/3 pt.	Deflections - in. Beam Wt. + Prestress	Deflections - in. Total DL + Prestress	Deflections - in. Live Load
39	39	51	8.830	1.910	1.671	4,376	4,419	0.349	0.239	1.24	12.59	17.84	-0.284	-0.190	0.317
39	42	46	9.475	1.663	1.456	4,384	4,409	0.330	0.227	1.24	14.16	20.38	-0.226	-0.149	0.262
39	45	42	10.141	1.468	1.285	4,413	4,424	0.312	0.215	1.24	15.92	23.32	-0.183	-0.119	0.221
40	42	49	9.475	1.772	1.551	4,596	4,665	0.329	0.224	1.25	13.79	19.85	-0.254	-0.169	0.289
40	45	45	10.141	1.573	1.377	4,615	4,680	0.313	0.214	1.24	15.35	22.45	-0.208	-0.136	0.243
41	42	51	9.475	1.844	1.614	4,795	4,825	0.330	0.224	1.24	13.45	19.37	-0.277	-0.183	0.316
41	45	47	10.141	1.643	1.438	4,815	4,871	0.313	0.213	1.24	15.01	21.95	-0.228	-0.149	0.266
41	48	44	10.826	1.489	1.303	4,836	4,931	0.298	0.203	1.24	16.56	24.63	-0.191	-0.125	0.226
42	42	54	9.475	1.953	1.709	5,003	5,056	0.331	0.223	1.24	13.05	18.78	-0.309	-0.205	0.346
42	45	49	10.141	1.713	1.499	5,024	5,055	0.314	0.212	1.24	14.63	21.39	-0.249	-0.163	0.291
42	48	46	10.826	1.557	1.362	5,040	5,141	0.297	0.201	1.24	16.20	24.09	-0.210	-0.137	0.247
43	45	51	10.141	1.783	1.561	5,228	5,231	0.315	0.212	1.24	14.28	20.89	-0.271	-0.176	0.317
43	48	48	10.826	1.624	1.422	5,251	5,343	0.298	0.201	1.24	15.81	23.50	-0.229	-0.149	0.270
44	45	54	10.141	1.888	1.652	5,433	5,483	0.314	0.211	1.24	13.91	20.25	-0.301	-0.197	0.345
44	48	50	10.826	1.692	1.481	5,457	5,533	0.298	0.200	1.24	15.46	22.88	-0.250	-0.162	0.293
45	48	52	10.826	1.760	1.540	5,666	5,726	0.299	0.201	1.24	15.10	22.18	-0.271	-0.175	0.318
46	48	54	10.826	1.827	1.599	5,874	5,907	0.300	0.202	1.24	14.76	21.53	-0.294	-0.189	0.344
47	48	56	10.826	1.895	1.659	6,080	6,081	0.302	0.203	1.24	14.40	20.91	-0.318	-0.204	0.371

DESIGN DATA--7'6" DOUBLE BOX, STRAIGHT STRANDS, NO TENSION

Span ft.	Depth of Box in.	No. of 1/2"ϕ 270 k Strands	C. G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in. Initial Prestress	Maximum Compressive Stress kips per sq. in. Final Prestress + All Loads	Ultimate Moment ft. kips Required	Ultimate Moment ft. kips Provided	Diagonal Tension kips per sq. in. 1/4 pt.	Diagonal Tension kips per sq. in. 1/3 pt.	Area of Stirrups in.^{2}	Required Stirrup Spacing - in. 1/4 pt.	Required Stirrup Spacing - in. 1/3 pt.	Deflections - in. Beam Wt. + Prestress	Deflections - in. Total DL + Prestress	Deflections - in. Live Load
26	33	29	7.479	1.114	0.975	2,247	2,271	0.390	0.279	1.24	14.38	20.58	-0.089	-0.060	0.106
27	33	31	7.479	1.191	1.042	2,388	2,409	0.395	0.282	1.24	13.82	19.65	-0.102	-0.069	0.121
28	33	33	7.479	1.267	1.109	2,538	2,544	0.399	0.285	1.24	13.32	18.82	-0.117	-0.178	0.138
29	33	36	7.479	1.383	1.210	2,697	2,743	0.400	0.284	1.24	12.83	18.03	-0.137	-0.092	0.157
30	33	38	7.479	1.459	1.277	2,857	2,872	0.404	0.286	1.24	12.43	17.39	-0.155	-0.104	0.177
30	36	34	8.058	1.260	1.103	2,868	2,892	0.372	0.265	1.24	14.35	20.44	-0.121	-0.080	0.142
31	33	41	7.479	1.575	1.378	3,017	3,063	0.404	0.285	1.24	12.03	16.76	-0.179	-0.120	0.200
31	36	36	8.058	1.334	1.168	3,029	3,040	0.374	0.266	1.24	13.92	19.73	-0.136	-0.090	0.160
32	33	43	7.479	1.652	1.445	3,178	3,187	0.406	0.287	1.24	11.71	16.26	-0.199	-9.133	0.224
32	36	39	8.058	1.445	1.265	3,191	3,258	0.372	0.263	1.24	13.50	19.06	-0.158	-0.105	0.179
32	39	35	8.661	1.253	1.097	3,204	3,253	0.347	0.246	1.24	15.42	22.17	-0.125	-0.082	0.147
33	33	46	7.479	1.767	1.546	3,342	3,369	0.409	0.286	1.24	11.31	15.74	-0.227	-0.152	0.249
33	36	41	8.058	1.519	1.330	3,355	3,400	0.376	0.264	1.24	13.06	18.48	-0.176	-0.117	0.200
33	39	37	8.661	1.324	1.159	3,369	3,416	0.350	0.246	1.24	14.90	21.47	-0.140	-0.092	0.164
34	33	49	7.479	1.882	1.647	3,506	3,523	0.415	0.288	1.24	10.84	15.12	-0.257	-0.172	0.277
34	36	43	8.058	1.593	1.395	3,520	3,541	0.380	0.264	1.24	12.66	17.96	-0.196	-0.129	0.222
34	39	39	8.661	1.396	1.222	3,535	3,577	0.353	0.246	1.24	14.43	20.83	-0.157	-0.102	0.182
35	36	46	8.058	1.705	1.492	3,683	3,747	0.380	0.262	1.24	12.28	17.45	-0.223	-0.148	0.246
35	39	41	8.661	1.468	1.285	3,699	3,736	0.355	0.246	1.24	14.02	20.27	-0.174	-0.114	0.201
35	42	38	9.286	1.316	1.151	3,714	3,805	0.331	0.230	1.24	15.81	23.27	-0.144	-0.093	0.167
36	36	48	8.058	1.779	1.557	3,845	3,853	0.388	0.265	1.24	11.83	16.62	-0.245	-0.161	0.271
36	39	43	8.661	1.539	1.347	3,861	3,892	0.358	0.245	1.24	13.63	19.74	-0.193	-0.125	0.221
36	42	39	9.286	1.350	1.182	3,877	3,894	0.336	0.232	1.24	15.40	22.70	-0.155	-0.099	0.184
37	36	51	8.058	1.890	1.654	4,052	4,074	0.385	0.263	1.24	11.59	16.38	-0.275	-0.182	0.301
37	39	46	8.661	1.647	1.441	4,069	4,076	0.363	0.249	1.24	13.04	18.69	-0.219	-0.143	0.246
37	42	42	9.286	1.454	1.273	4,086	4,155	0.334	0.230	1.24	14.95	21.84	-0.177	-0.114	0.205
38	39	49	8.661	1.754	1.535	4,253	4,330	0.357	0.245	1.24	12.83	18.29	-0.246	-0.162	0.271
38	42	44	9.286	1.523	1.333	4,271	4,326	0.335	0.231	1.24	14.58	21.15	-0.195	-0.126	0.225
38	45	40	9.932	1.341	1.173	4,289	4,303	0.318	0.220	1.24	16.34	24.13	-0.158	-0.100	0.190

DESIGN DATA--7'6" DOUBLE BOX, STRAIGHT STRANDS, NO TENSION (cont.)

Span ft.	Depth of Box in.	No. of 1/2"♦ 270 k Strands	C. G. of Strands from Bottom of Box, in.	Maximum Compressive Stress kips per sq. in.		Ultimate Moment ft. kips		Diagonal Tension kips per sq. in.		Area of Stirrups in.^{2}	Required Stirrup Spacing - in.		Deflections - in.		
				Initial Prestress	Final Prestress + All Loads	Required	Provided	1/4 pt.	1/3 pt.		1/4 pt.	1/3 pt.	Beam Wt. + Prestress	Total DL + Prestress	Live Load
39	39	51	8.661	1.826	1.598	4,446	4,491	0.358	0.246	1.24	12.55	17.83	-0.269	-0.176	0.298
39	42	47	9.286	1.627	1.424	4,453	4,546	0.338	0.232	1.24	14.03	20.22	-0.221	-0.143	0.247
39	45	42	9.932	1.408	1.232	4,483	4,492	0.319	0.220	1.24	15.90	23.36	-0.175	-0.110	0.208
40	42	49	9.286	1.697	1.485	4,669	4,729	0.338	0.231	1.24	13.71	19.78	-0.242	-0.156	0.272
40	45	45	9.932	1.508	1.320	4,688	4,772	0.318	0.218	1.24	15.41	22.62	-0.198	-0.126	0.229
41	42	51	9.286	1.766	1.546	4,871	4,904	0.339	0.230	1.24	13.41	19.37	-0.264	-0.170	0.298
41	45	47	9.932	1.576	1.379	4,892	4,925	0.323	0.220	1.24	14.88	21.80	-0.217	-0.138	0.251
41	48	43	10.597	1.397	1.223	4,912	4,929	0.305	0.208	1.24	16.69	24.92	-0.177	-0.111	0.214
42	42	54	9.286	1.870	1.636	5,083	5,155	0.339	0.228	1.24	13.06	18.86	-0.294	-0.190	0.326
42	45	49	9.932	1.643	1.438	5,105	5,124	0.323	0.219	1.24	14.55	21.32	-0.237	-0.150	0.274
42	48	45	10.597	1.462	1.280	5,120	5,131	0.306	0.208	1.24	16.25	24.25	-0.194	-0.121	0.233
43	45	51	9.932	1.710	1.496	5,312	5,315	0.324	0.218	1.24	14.24	20.88	-0.258	-0.163	0.299
43	48	48	10.597	1.599	1.365	5,335	5,410	0.307	0.207	1.24	15.71	23.38	-0.219	-0.138	0.255
44	45	53	9.932	1.810	1.584	5,521	5,588	0.321	0.216	1.24	13.92	20.33	-0.287	-0.182	0.325
44	48	50	10.597	1.624	1.422	5,544	5,620	0.306	0.206	1.24	15.40	22.84	-0.238	-0.150	0.277
45	48	52	10.597	1.689	1.479	5,758	5,822	0.307	0.207	1.24	15.08	22.21	-0.259	-0.162	0.300
46	48	54	10.597	1.754	1.536	5,969	6,017	0.307	0.207	1.24	14.77	21.62	-0.280	-0.175	0.325
47	48	56	10.597	1.819	1.592	6,180	6,205	0.308	0.208	1.24	14.45	21.05	-0.303	-0.188	0.350

APPLICATION OF DESIGN TABLES

Beams with straight parallel strands designed from the tables required the additional mild steel reinforcement developed and published by the AREA for box beams. Spans up to 40 ft may be detailed as through-voided beams. Spans exceeding 40 ft shall have end diaphragms unless an analysis is made to develop appropriate reinforcement details for a through-voided girder. The reinforcement details published by the AREA must be adjusted to accommodate the deeper sections and the stirrup spacings included in the design tables according to standard detailing practice. The stirrup spacings in the tables should be rounded down to practical values.

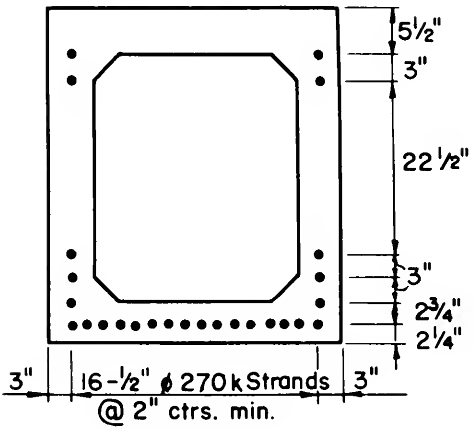
For the designs permitting tension, where the tensile stress exceeds $3\sqrt{f_{ci}}$, non-prestressed reinforcement must be provided to resist the total tensile force in the concrete computed on the basis of an uncracked section. The total tensile force in the concrete can be calculated by assuming a straight line stress variation between the tensile stress and compressive stress in the extreme fibers under the initial prestress force. This auxiliary reinforcement is required to the point where the stress is reduced to $3\sqrt{f_{ci}}$ by bending stresses due to beam dead load. The steel must be extended beyond this point sufficiently to develop the bars in bond.

After adjusting the mild steel reinforcement details for the span and depth of box under consideration and providing any necessary tensile reinforcement, the only remaining requirement is to provide a strand pattern with the number of strands and strand center of gravity shown in the tables. This is illustrated for single-celled and double-celled box beams without tension with straight parallel strands in the following calculations. The same calculation procedure is used for beams with tension in the top slab. However, the tension designs provide a lower center of gravity for the prestressing steel. For this reason strands are not required near the top of the box section.

Application of the design tables to box beams with harped strands is similar to that for straight strands except that calculations are required for the strand center of gravity both at the beam end and at the hold-down, or ⅓ point. The required center of gravity figures for these points are found in the design tables under columns headed YE and YM, respectively.

3'-0" Wide Box Beam, 42" Deep, 40' Span,
Straight Parallel Strands, No Tension

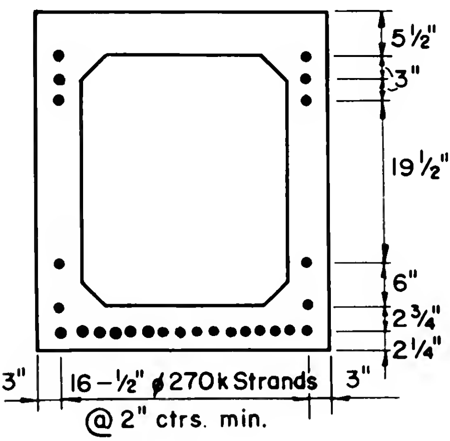
From design tables; 26 strands are required with a center of gravity 10.377" above the bottom of the box. Try the pattern shown below:



(1) Number of 1/2"ȼ 270K Strands	(2) Distance from bottom of box - in.	(1) X (2)
16	2.25	36.00
2	5.00	10.00
2	8.00	16.00
2	11.00	22.00
2	33.50	67.00
2	36.50	73.00
Σ = 26		Σ = 224.00

$$c.g. = \frac{224.00}{26} = 8.611 \text{ in.}$$ - too low

Adjust strand pattern as below to get required center of gravity:

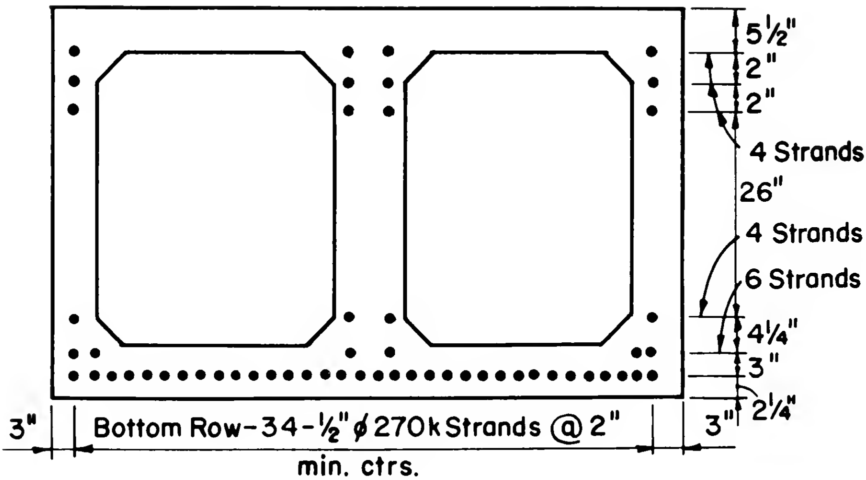


(1) Number of 1/2"ȼ 270K Strands	(2) Distance from bottom of box - in.	(1) X (2)
16	2.25	36.00
2	5.00	10.00
2	11.00	22.00
2	30.50	61.00
2	33.50	67.00
2	36.50	73.00
Σ = 26		Σ = 269.00

$$c.g. = \frac{269.00}{26} = 10.384 \text{ in.}$$ - close enough

6'-0" Wide Double Box Beam, 45" Deep
44' Span, Straight Parallel Strands, No Tension

From design tables, 56 strands are required with a center of gravity 10.619" above the bottom of the box. After making a preliminary rough calculation, the required center of gravity is provided as follows:



(1) Number of 1/2"ϕ 270K Strands	(2) Distance from bottom of box - in.	(1) X (2)
34	2.25	76.50
6	5.25	31.50
4	9.50	38.00
4	35.50	142.00
4	37.50	150.00
4	39.50	158.00
Σ = 56		Σ = 596.00

$$c.g. = \frac{596.00}{56} = 10.642 \text{ in.} \text{ - close enough}$$

Report on Assignment 8

Waterproofing for Railway Structures

Collaborating with Committees 6, 7, and 15

J. R. Iwinski (chairman, subcommittee), E. L. Bangs, E. R. Blewitt, J. W. Dolson, A. K. Howe, L. Lange, Jr., R. E. Pearson, M. Pikarsky, H. D. Reilly, H. H. Schmidt, E. A. Watson, J. M. Williams.

The status of the investigations being conducted under this assignment is as follows:

(a) Investigate Types of Membrane Protection: Currently, tests of butyl rubber membrane, with and without protective coverings, are being conducted at the AAR Laboratory in Chicago. No results are available.

(b) Investigate Types of Joint Sealers: Data concerning application, availability, etc. are currently being compiled. No definite recommendations are yet available.

Report of Committee 30—Impact and Bridge Stresses

°N. E. **Ekrem**, *Chairman*
°P. L. **Montgomery**, *Vice Chairman*

°**D. S. Bechly**
°**J. A. Erskine**
°**C. V. Lund**
°**E. R. Andrlik**
L. N. Bigelow
E. S. Birkenwald
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G. F. Dalquist
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K. L. DeBlois
O. J. Duffy
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L. R. Kubacki
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W. W. Sanders, Jr.
M. B. Scott
R. L. Shipley
C. B. Smith
H. Solarte
J. E. South
J. D. Tapp, Jr.
G. S. Vincent
C. T. Webster
M. E. Weller
J. R. Williams
E. N. Wilson
D. R. Wright

Committee

Those whose names are shown in boldface, in addition to the chairman and vice chairman, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 30.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Steel, collaborating with Committee 15.
   Progress report, presented as information .... page 450

2. Concrete, collaborating with Committee 8.
   Progress report, presented as information .... page 451

3. Timber, collaborating with Committee 7.
   No progress was made on this subject because funds were not allocated to carry out needed research.

4. Electronic computers, collaborating with Committees 15, 16 and 32.
   Progress report, submitted as information .... page 452

The Committee on Impact and Bridge Stresses,
N. E. Ekrem, *Chairman*.

AREA Bulletin 611, January 1968.

Armour Townsend Granger
1898-1966

Armour Townsend Granger was born in Austin, Tex., on March 21, 1898. He graduated from the University of Texas with the degrees, Bachelor of Science in Civil Engineering, and Civil Engineering. After spending nearly two years as a detailer and designer for Harrington, Howard and Ash, consulting engineers, in Kansas City, he returned to the University of Texas where he held various teaching posts for nearly eight years. During the following 11 years he was assistant engineer for Ash–Howard–Needles & Tammen, consulting engineers, in Kansas City and New York.

He then returned to teaching as associate professor at the University of Tennessee and in a short time became professor and head of the Department of Civil Engineering there. Shortly before his death he had resigned the position of dean of the College of Engineering to return to full-time teaching as a professor in the Civil Engineering Department.

Professor Granger became a member of AREA in 1949 and was an active member of Committee 30—Impact and Bridge Stresses, from 1953 until the time of his death. During a part of that time he was chairman of one of its important subcommittees and is remembered for his lively participation in committee discussions.

C. E. Ekberg, Jr.
K. L. DeBlois
E. D. Ripple
J. D. Tapp, Jr.
J. R. Williams
Committee on Memoir.

Report on Assignment 1

Steel

Collaborating with Committee 15

D. S. Bechly (chairman, subcommittee), L. N. Bigelow, E. S. Birkenwald, G. F. Dalquist, O. J. Duffy, L. R. Kubacki, J. F. Marsh, James Michalos, W. H. Munse, D. W. Musser, A. L. Piepmeier, M. J. Plumb, C. A. Roberts, C. R. Sanders, W. W. Sanders, Jr., H. Solarte, J. E. South, G. S. Vincent, M. E. Weller.

Under this assignment progress is reported in determining the live-load and impact stresses occurring in steel truss spans of modern design from field tests under the passage of diesel locomotives and high-capacity freight cars. Reports on field tests conducted in 1965 on 300- and 400-ft steel truss spans in a Southern Pacific Company bridge near Del Rio, Tex., and in 1966 on a 200-ft truss span in a Great

Northern Railway bridge near Priest River, Idaho, have been prepared by the AAR Research Center staff, reviewed by the committee, and approved for publication.

The two reports that have been completed will be supplemented by additional tests on other spans to furnish a compilation of results covering a complete range of span lengths, truss types and variations in speed and loadings. Field testing was performed this year on a second 200-ft truss span, this one on the Burlington Lines near Sumner, Mo., and the results are being analysed. Selection is currently being made of a span for testing next year, preferably one in the 300- to 400-ft range.

On the truss spans for which reports have been completed, the one outstanding difference that has been observed between the recorded and calculated stresses has been in the floorbeam hangers of the 300- and 400-ft spans. These hangers had a very high bending stress in the plane of the truss in addition to the bending normally expected in the plane of the floorbeam. Another apparent exception to design theory was observed in the measured roll factor of the impact stress in various members. Using the roll factor in the present impact formula, this portion of the impact stress would be two to three times greater in the stringers of a truss span than in the floorbeams or truss members. The stresses as measured in these tests indicate a much more uniform value in all members.

In addition to the measurement of live-load and impact stresses, field measurements on the frequency of maximum stresses are included in the report on the truss spans on the Southern Pacific. Additional investigations are also planned on this subject, and frequency measurements were taken by the Research Center staff during the past year for a period of one week on the stringers and floorbeams of a through plate-girder span bridge on the Chicago & North Western Railway near Geneva, Ill.

Report on Assignment 2

Concrete

Collaborating with Committee 8

J. A. Erskine (chairman, subcommittee), K. L. DeBlois, C. E. Ekberg, Jr., J. F. Hoss, Jr., W. R. Hyma, G. F. Leyh, C. V. Lund, Z. L. Moh, P. L. Montgomery, N. M. Newmark, E. D. Ripple, M. B. Scott, R. L. Shipley, C. B. Smith, J. D. Tapp, Jr., C. D. Webster, J. R. Williams.

During the past year the test program, begun several years ago, for the determination of impact effects in prestressed concrete bridges was interrupted due to lack of suitable test bridges having span lengths in the neighborhood of 50 ft and longer. Several bridges of the required length are now available and it is planned to resume the test program next year.

This subcommittee has also been given responsibility for an assignment on longitudinal forces in bridge structures, although this subject deals with structures of steel and timber, as well as concrete. A summary of 13 tests conducted by the AAR research staff, from which data on longitudinal forces were secured, was furnished the members of the subcommittee for study. Also, through correspondence, information was secured regarding similar investigations conducted in Europe and India.

It is planned to present a comprehensive summary of the tests made by the AAR on this subject, together with a discussion of the results, next year.

Report on Assignment 4

Electronic Computers

Collaborating with Committees 15, 16 and 32

E. R. Andrlik (chairman, subcommittee), A. J. S. Carr, J. W. Davidson, N. E. Ekrem, D. J. Engle, R. J. Fisher, A. D. M. Lewis, D. F. Lyons, C. H. Newlin, M. Noyszewski, E. N. Wilson, D. R. Wright.

During 1967 a computer program for analysis of railway truss bridges was prepared under the guidance of this committee. The program was written in FORTRAN by E. N. Wilson, a member of Committee 30, with funds provided by the AAR.

From input specifying the dead loading, live loading and truss geometry, the program calculates dead-load, live-load, impact and total stresses in the truss members. The program can be used for simple or continuous spans and for spans with counter diagonals. The truss is limited to 25 panels or 620 ft in length. The program was written as a basic railroad truss program, and its subroutines are designed to make the program flexible for future changes or other adaptations.

The Truss Program and the Moving-Load Program are available from the AAR at a nominal charge. The committee plans next to develop a simplified truss program for common forms of trusses and a program for rating truss bridges.

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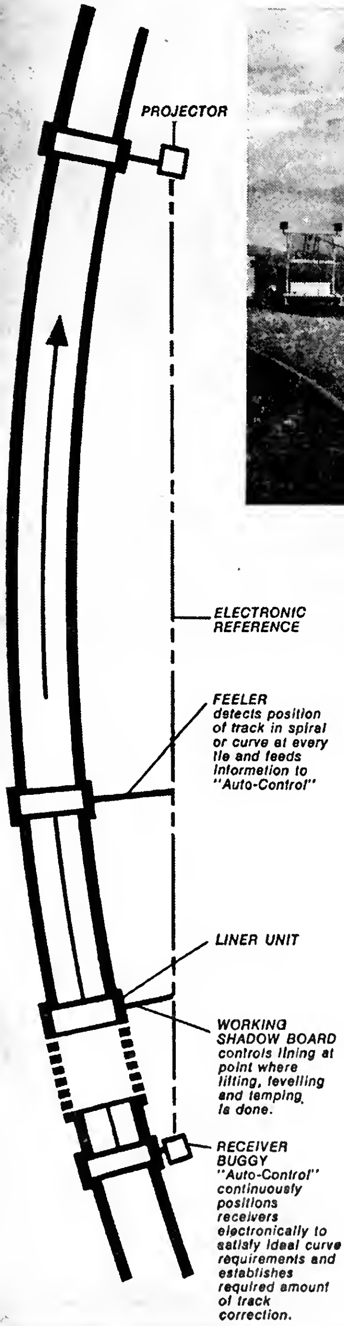

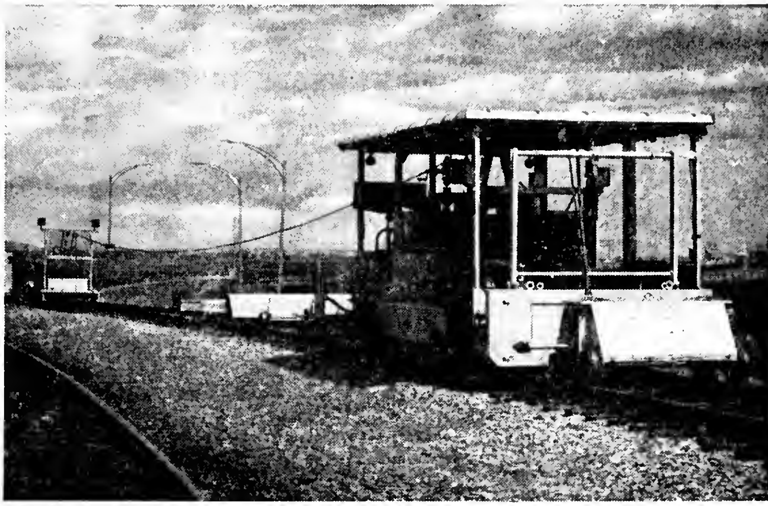

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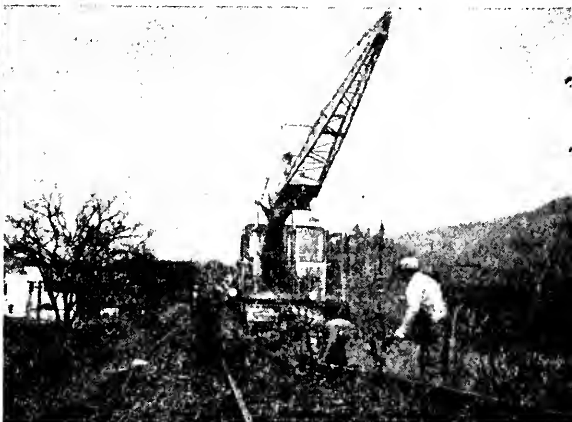

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Report of Committee 15—Iron and Steel Structures

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°**M. L. Koehler**, *Vice Chairman*
J. M. Hayes, *Secretary*
°**E. S. Birkenwald**
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R. N. Wagnon
H. T. Welty (E)
R. H. Wengenroth
W. Wilbur
A. R. Wilson (E)†
A. J. Wood
M. O. Woxland

Committee

(E) Member Emeritus
† Died May 3, 1967.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 15.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Revisions of specifications submitted for adoption have been published in the Manual Recommendations Supplement to Bulletin 610, December 1967.

1 (a). Complete Revision of Chapter 15 of the Manual.
   Revisions of specifications submitted as information, to be considered for adoption at a later date .... page 456

3. Protection of steel surfaces.
   Progress report, submitted as information .... page 503

7. Bibliography and technical explanation of various requirements in the AREA specifications relating to iron and steel structures.
   Brief progress report, submitted as information .... page 504

8. Specifications for corrugated structural steel plate pipe, pipe-arches and arches.

   Your committee recommends adoption of the revisions to the Manual as set forth in the report on Assignment 1 as published in the Manual Recommendations Supplement to Bulletin 610, December 1967.

10. Continuous welded rail on bridges, collaborating as necessary or desirable with Committee 31.

    Your committee continues to accumulate and review data on the use of continuous welded rail on bridges, but has no recommendation to to make at this time.

THE COMMITTEE ON IRON AND STEEL STRUCTURES,
D. L. NORD, *Chairman.*

AREA Bulletin 611, January 1968.

Allen Rutherford Wilson
1877-1967

Allen Rutherford Wilson, retired engineer of bridges and buildings, The Pennsylvania Railroad, president of AREA during 1936–37 and Life Member from 1949, died at Lansdowne, Pa., on May 3, 1967, at the age of 90.

Mr. Wilson, the son of W. H. and Rebecca A. Wilson, was born on January 15, 1877, in Bordentown, N. J. He attended the public school at Bordentown, the state normal school at Trenton, N. J., and was graduated from the mechanical engineering course at Drexel Institute, Philadelphia, Pa., in 1896.

Prior to his service with the Pennsylvania, he was employed for a short period by a machine tool builder in Philadelphia and by the New Jersey Steel & Iron Company at Trenton. He then became associated with American Bridge Company, serving as representative of its mechanical engineering department in the reconstruction of its Trenton plant.

Mr. Wilson entered the service of the Pennsylvania in July 1902 as a draftsman in the office of the engineer of bridges and buildings, where he specialized in the design of drawbridges, turntables, transfer bridges and other structures involving the use of machinery. He was appointed assistant engineer in March 1920, assistant engineer of bridges in May 1920, and engineer of bridges and buildings on March 1, 1927, which position he held until his retirement on January 31, 1947.

Mr. Wilson became a member of the AREA in 1924. Shortly thereafter he was assigned to the Committee on Iron and Steel Structures, serving as vice chairman from 1926 to 1928 and chairman from 1929 to 1934. During his administration as chairman, the Specifications for Steel Railway Bridges were completely rewritten, and numerous papers were published in the AREA Proceedings which served as the bases for the adoption of these specifications. His interest in welding, then a pioneer art, led to the publication of tentative specifications for fusion welding and gas cutting for steel structures. As a representative of Committee 15 and the Association on the Welding Research Council, he fathered the first comprehensive welding specifications for highway and railway bridges. On his retirement, he was elected Member Emeritus of Committee 15.

In 1942, Mr. Wilson became a member of the Special Committee on Impact which was later changed to the Committee on Impact and Bridge Stresses and remained on this committee until his retirement.

Mr. Wilson was a Life Member of American Society of Civil Engineers, having been elected as a Member in 1920 and made a Fellow in 1959.

On September 9, 1898, Mr. Wilson married Miss Eva Taylor of Bordentown, N. J., and had five children—Grace, Helen, Harold, Edythe and Dorothy.

Mr. Wilson was active in church work, having been senior deacon of the Lansdowne Baptist Church.

Report on Assignment 1 (a)

Complete Revision of Chapter 15 of the Manual

G. W. Salmon (chairman, subcommittee), T. J. Boyle, L. F. Currier, J. L. Durkee, G. K. Gillan, J. M. Hayes, A. Hedefine, M. L. Koehler, D. V. Messman, W. M. Thatcher.

Your committee presents as information the following recommendations with respect to Chapter 15 of the Manual, to be considered for adoption at a later date:

Pages 15—1—1 to 15—1—58, incl.

SPECIFICATIONS FOR STEEL RAILWAY BRIDGES

Substitute the following for the Foreword, page 15–1–1 and Section A, Pages 15–1–3 to 15–1–32, incl.:

FOREWORD

The purpose of these specifications is to formulate specific and detailed rules as a guide for the design, fabrication and erection of fixed bridges. The intention is to describe the best general practice for standard American railways, and to advance the causes of good design and workmanship.

These specifications are intended to apply to fixed spans not exceeding 400 ft. The requirements, however, apply in general to spans of any length, but special provisions should be added by the company, if and as required, for spans longer than 400 ft.

Provisions for welding of railway bridges are included in these specifications. Many requirements are taken directly or with slight modifications from the Specifications for Welded Highway and Railway Bridges (AWS D2.0) of the American Welding Society, and grateful acknowledgment is hereby made to the American Welding Society for permission to reproduce this material. Reference should be made to those specifications for information relative to welding procedures and processes, and for other welding requirements not covered herein.

1.0 DESIGN

1.1 PROPOSALS AND DRAWINGS

1.1.1 Definition of Terms

(a) The term "company" means the railway company party to the contract. The term "engineer" means the chief engineer of the company or his authorized representatives. The term "inspector" means the inspector representing the company. The term "contractor" means the manufacturing or fabricating contractor party to the contract.

1.1.2 Proposals

(a) Bidders shall submit proposals conforming to the terms in the letter of invitation. The proposals preferably shall be based on plans and specifications furnished by the company. Such plans will show the conditions determining the design of the bridge, the general dimensions, stresses, and typical details.

(b) If the invitation requires the contractor to furnish the design, the invitation shall state the general conditions at the site, such as the track spacing, character of foundations, presence of old structures, traffic conditions, etc.

1.1.3 Shop Drawings

(a) After the contract has been awarded, the contractor shall submit to the engineer, for review and approval as to conformity to contract requirements, prints from checked plans in the number required, of stress sheets, shop drawings and erection procedures, unless such sheets, drawings and procedures have been prepared by the company.

(b) Welding symbols shall be those shown in the latest edition of Standard Welding Symbols (AWS A2.0) of the American Welding Society. Special conditions shall be fully explained by added notes or details.

(c) Shop drawings shall be preferably 24 inches by 36 inches in size, including left hand margin 1½ inches wide and ½-inch margin on other edges. An approved title shall be in the lower right-hand corner.

(d) If any changes or corrections are required by the engineer, one print with changes noted thereon shall be returned to the contractor. Prints from corrected plans shall be submitted to the engineer for review, and this procedure will continue until each drawing, etc., is approved.

(e) No change shall be made on such approved drawings without the consent of the engineer.

(f) The contractor shall furnish to the company as many prints of the drawings as may be necessary to carry out the work.

(g) The contractor shall be responsible for the correctness and completeness of his drawings, regardless of any approval by the engineer.

(h) Any work performed or material ordered prior to approval by the engineer shall be at the sole risk of the contractor.

(i) The original drawings shall be ink on tracing cloth or legible drawings reproduced by an approved method. They shall be delivered to and become the property of the company upon completion of the contract.

1.1.4 Drawings to Govern

(a) If the drawings and the specifications conflict, the drawings shall govern.

1.1.5 Patented Devices

(a) The contractor shall protect the company against claims arising from the use of patented devices or parts proposed by him.

1.1.6 Notice to Engineer

(a) No material shall be rolled or work done before the engineer has been notified where the orders have been placed.

1.2 GENERAL FEATURES OF DESIGN

1.2.1 Materials

(a) The design and workmanship requirements covered by 1.0, 2.0, 3.0 and 4.0 of these specifications are based on the use of materials conforming to the requirements of the following current ASTM specifications:

Structural steel	A 36.
When this steel is used for welded bridge construction where improved notch toughness is important, the engineer shall specify that the material shall be silicon killed fine grain practice, or, for plates and bars ¾ inch and less in thickness and for shapes, that it shall be other than rimmed or capped steel and that it shall have a manganese content not less than 0.60 percent ladle analysis, 0.57 percent check analysis.	
Rivet steel	A 502, Grade 1.
High-strength bolts	A 325 and A 490.
Machine bolts	A 307
Cast steel, for shoes	A 27, Grade 63–35
Forged steel, for large pins and large expansion rollers	A 235, Classs E
Structural steel, weathering type	A 242 modified,
and A 441 modified, with atmospheric corrosion resistance at least 4 times that of A 36, and weldable when applicable.	
Wrought iron	A 42
Bronze, for bearing and expansion plates:	
Cast plates	B 22
Rolled plates	B 100
Welding electrodes for manual shielded metal-arc welding	A 233
Welding electrodes and flux for submerged arc welding	A 558
Welding electrodes for gas metal-arc welding with carbon dioxide shielding	A 559
Welding electrodes for manual shielded metal-arc welding of weathering type structural steel	A 316, EXXXX-G
with chemistry consistent with the chemistry of the base metal.	

1.2.2 Types of Bridges

(a) The preferred types of bridges are as follows:
Rolled, or welded beams for spans up to 50 ft.
Riveted, bolted, or welded plate girders for spans up to 150 ft.
Riveted, bolted, or welded trusses for spans over 150 ft.

(b) Pin connected trusses may be used for unusual conditions, but special provisions applicable to their design and construction shall be prepared and furnished by the engineer.

1.2.3 Spacing of Trusses, Girders, and Stringers

(a) The distance between centers of outside trusses or girders shall be sufficient to prevent overturning by the specified lateral forces. In no case shall it be less than 1/20 of the span for through spans, nor 1/15 of the span for deck spans.

(b) Where the track is supported by a pair of deck girders or stringers, the distance center to center shall be not less than 6 feet 6 inches. If multiple girders or stringers are used, they shall be arranged as nearly as possible to distribute the track load uniformly to all members.

1.2.4 Deflection

(a) The deflection of the structure shall be computed for the live loading plus impact condition producing the maximum stress at mid-span for simple spans. In this computation, gross moment of inertia shall be used for flexural members, and gross area of members for trusses, except that for members with perforated cover plates, the effective area shall be used. The effective area shall be the gross area reduced by the area determined by dividing the volume of a perforation by the distance center to center of perforations.

(b) The structure shall be so designed that the computed deflection shall not exceed 1/640 of the span length center to center of bearings for simple spans.

1.2.5 Clearances

(a) The clearances on straight track shall not be less than those shown in Fig. 1. On curved track, the lateral clearances shall be increased for the mid-ordinate and overhang of a car 88 ft long and 62 ft between centers of trucks,

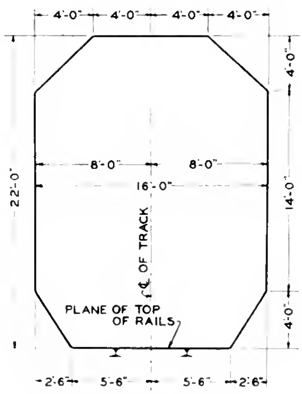

Fig. 1

equivalent to 1 inch per degree of curvature. When the fixed obstruction is on tangent track but the track is curved within 75 ft of the obstruction, the lateral clearances shall be increased for such a car.

(b) Where legal requirements specify greater clearances, such requirements shall govern.

(c) The superelevation of the outer rail shall be specified by the engineer. The distance from the top of rail to the top of tie shall be taken as 8 inches, or as specified by the engineer.

1.2.6 Dimensions for Calculations of Stresses

(a) The span or length shall be assumed as:

For trusses and girders, the distance between centers of bearings.

For truss members, the distance between centers of joints.
For floorbeams, the distance between centers of trusses or girders.
For stringers, the distance between centers of floorbeams.
For timber bridge ties, the clear distance between supports plus 6 inches.

(b) The depth shall be assumed as:
For trusses, the distance between gravity axes of chords.

1-.2.7 Skew Bridges

(a) At the ends of skew bridges, the ends of the supports for each track shall be square with the line of the track.

1.2.8 Open Deck

(a) Timber bridge ties shall be preferably not less than 10 ft long, and spaced not more than 6 inches apart. They shall be secured against bunching.

1.2.9 Camber

(a) The camber of trusses shall be equal to the deflection produced by the dead load plus a load of 3000 lb per ft of track. The camber of plate girders more than 90 ft in length shall be equal to the deflection produced by the dead load only. Plate girders 90 ft or less in length and rolled beams need not be cambered.

1.2.10 Name Plates

(a)Attached to the end of the each span, at a point convenient for inspection, there shall be a name plate showing in raised letters and figures the name of the fabricator and the year of construction.

1.3 LOADS AND STRESSES

1.3.1 Loads and Forces

(a) Bridges shall be proportioned for the following loads and forces:

1. Dead load.
2. Live load.
3. Impact.
4. Contrifugal force.
5. Other lateral forces.
6. Longitudinal force.

(b) Stresses from each of these loads and forces shall be shown separately on the stress sheet.

1.3.2 Dead Load

(a) In estimating the weight for the purpose of computing dead load stresses, the following unit weights shall be used:

	Pounds per Cubic Foot
Steel	490
Concrete	150
Sand, gravel, and ballast	120
Asphalt-mastic and bituminous macadam	150
Granite	170
Paving bricks	150
Timber	60

(b) The track rails, inside guard rails, and fastenings shall be assumed to weigh 200 lb per lin ft for each track.

1.3.3 Live Load

(a) The recommended live load for each track is the Cooper E 80 load, shown in Fig. 2.

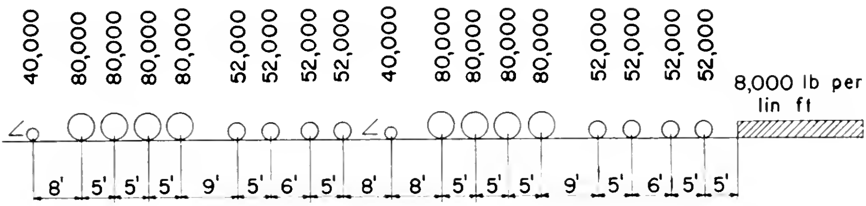

Fig. 2

(b) The engineer shall specify the live load to be used, such load to be proportional to the recommended load, with the same axle spacing.

(c) For bridges on curves, provision shall be made for the increased proportion carried by any truss, girder, or stringer due to the eccentricity of the load.

(d) For members receiving load from more than one track, the proportions of full live load on the tracks shall be as follows:

For two tracks, full live load.

For three tracks, full live load on two tracks and ½ on the other track.

For four tracks, full live load on two tracks, ½ on one track, and ¼ on the remaining one.

For more than four tracks, as specified by the engineer.

The selection of the tracks for these proportions shall be such as will give the greatest live-load stress.

1.3.4 Distribution of Live Load

1.3.4.1 Timber Ties

(a) Timber bridge ties shall be designed on the assumption that the maximum wheel load on a rail is distributed over three ties, and is applied without impact.

1.3.4.2 Tranverse Steel Beams (No Stringers).

(a) For open or ballasted track carried on transverse steel beams without stringers, the portion of any axle load on a single beam shall be as follows:

$$P = \frac{1.15\ AD}{S}$$

P = load on a beam from one track.
A = axle load.
S = axle spacing in feet.
D = effective beam spacing. For moment,

$$D = d\left(\frac{1}{1 + d/aH}\right)\left(0.4 + \frac{1}{d} + \frac{\sqrt{H}}{12}\right),\ \text{but not greater than } d \text{ or } S.$$

For end shear, $D = d$.

d = beam spacing in feet.

a = beam span in feet.

$H = \frac{n\, I_b}{a\, h^3}$.

n = the ratio of the modulus of elasticity of steel to that of concrete.

I_b = moment of inertia of beam in inches^4.

h = thickness of concrete deck slab in inches.

Note: $D = d$ for bridges with no concrete deck; or with slabs less than 6 inches thick; or for bridges where the concrete slab extends over less than the center 75 percent of the floorbeam.

(b) The load P shall be assumed distributed as concentrated loads on the beam under each rail.

(c) The effects of eccentricity of track and centrifugal force shall be included.

(d) Where d exceeds S, P shall be the reaction of the axle loads, assuming that the flooring between beams acts as a simple span.

1.3.4..3 Longitudinal Steel Beams or Girders.

(a) For ballasted-deck bridges, with standard cross ties and not less than 6 inches of ballast under the ties, supported by longitudinal beams or girders, the live load may be assumed as uniformly distributed over a width equal to the length of the tie plus twice the minimum distance from the bottom of the tie to the top of the beams or girders, centered on the intersection of the center line of track with the plane of the base of rails, but not to exceed the distance between track centers of multiple tracks. All beams whose centroid is within this width may be assumed as equally loaded.

(b) In open-deck structures, where two or more longitudinal beams per rail are properly diaphragmed and symmetrically spaced under the rail, they may be considered as equally loaded.

1.3.5 Impact

(a) To the axle loads specified in Art. 1.3.3 there shall be added impact loads applied at top of rail and distributed thence to the supporting members. The impact loads shall be a percentage of the axle load specified in Art. 1.3.3 and shall be applied vertically at top of rail. For open-deck bridges the percentage to be used shall be determined by the applicable formula below. For ballasted-deck bridges the percentage to be used shall be 90 percent of that specified for open-deck bridges.

1. For rolling equipment without hammer blow (diesels, electric locomotives, tenders alone, etc.):

   For L less than 80 ft .... $\frac{100}{S} + 40 - \frac{3L^2}{1600}$

   For L 80 ft or more .... $\frac{100}{S} + 16 + \frac{600}{L-30}$

2. For steam locomotives with hammer blow:

   A. For beam spans, stringers, girders, floorbeams, posts of deck truss spans carrying load from floorbeam only, and floorbeam hangers:

   For L less than 100 ft .... $\frac{100}{S} + 60 - \frac{L^2}{500}$

For L 100 ft or more .... $\frac{100}{S} + 10 + \frac{1800}{L - 40}$

B. For truss spans .... $\frac{100}{S} + 15 + \frac{4000}{L + 25}$

where S = distance center to center of beams, girders or trusses, used singly or in groups.

L = length, in feet, center to center of supports for stringers, transverse floorbeams without stringers, longitudinal girders and trusses (main members), or

L = length, in feet, of the longer adjacent supported stringers, longitudinal beam, girder or truss for impact in floorbeams, floorbeam hangers, subdiagonals of trusses, transverse girders, supports for longitudinal and transverse girders and viaduct columns.

(b) For members receiving load from more than one track, the impact percentage shall be applied to the static live load on the number of tracks shown below:

Load received from:

Two tracks:

For L less than 175 ft ...... Full impact on two tracks.

For L from 175 ft to 225 ft .. Full impact on one track and a percentage of full impact on the other as given by the formula, $450 - 2L$.

For L greater than 225 ft .... Full impact on one track and none on the other.

More than two tracks:

For all values of L .... Full impact on any two tracks.

1.3.6 Centrifugal Force

(a) On curves, a centrifugal force corresponding to each axle load shall be applied horizontally through a point 6 ft above the top of rail measured along a line perpendicular to the line joining the tops of the rails and equidistant from them. This force shall equal the percentage $0.00117S^2D$ of the specified axle load without impact.

S = speed in miles per hour

D = degree of curve

(b) On curves, each axle load on each track shall be applied vertically through the point defined in the first paragraph of this article. The impact forces shall be computed and applied as specified in Art. 1.3.5.

(c) Preferably the section of the stringer, girder or truss on the high side of the superelevated track shall be used also for the member on the low side, if this is greater than the computed section of the latter. If, under the foregoing provisions, the member on the low side shall be computed for the increased live load forces due thereto, no impact forces shall be added except upon estimating a speed consistent therewith, including the relief from the centrifugal force at such speed. If such computations require greater section in the member on the low side, it shall be so designed.

(d) The relationship between the centrifugal force defined above and the permissible speed for a superelevation assumed to be 3 inches less than that required for zero resultant flange pressure between wheel and rail may be expressed by the following formulas:

$$C = 0.00117S^2D = 1.755\ (E + 3)$$

$$E = \frac{S^2D}{1500} - 3 = \frac{C - 5.265}{1.755}$$

$$S = \frac{1500}{D}\ (E + 3)$$

in which

D = degree of curve

E = actual superelevation in inches

S = permissible speed in miles per hour

C = centrifugal force in percentage of the live load

1.3.7 Wind on Loaded Bridge

(a) The wind force shall be considered as a moving load acting in any horizontal direction. On the train it shall be taken at 300 lb per lin ft on the one track, applied 8 ft above the top of rail. On the bridge it shall be taken at 30 lb per sq ft of the following surfaces:

(1) For girder spans, 1½ times the vertical projection of the span.

(2) For truss spans, the vertical projection of the span plus any portion of the leeward trusses not shielded by the floor system.

(3) For viaduct towers and bents, the vertical projections of all columns and tower bracing.

(b) The wind force on girder spans and truss spans, however, shall not be taken at less than 200 lb per lin ft for the loaded chord or flange, and 150 lb per lin ft for the unloaded chord or flange.

1.3.8 Wind on Unloaded Bridge

(a) If a wind force on the unloaded bridge of 50 lb per sq ft of surface as defined in Art. 1.3.7, combined with the dead load, produces greater stresses than those produced by the wind forces specified in Art. 1.3.7, combined with the stresses from dead load, live load, impact, and centrifugal force, the members wherein such greater stresses occur shall be designed therefor.

1.3.9 Nosing of Locomotives

(a) For bracing systems or for longitudinal members entirely without a bracing system, the lateral force to provide for the effect of the nosing of locomotives (in addition to the other lateral forces specified) shall be a single moving force of 20,000 lb applied at the top of the rail, in either lateral direction, at any point of the span. On spans supporting multiple tracks, the nosing effect from only one track shall be used. The resulting vertical forces shall be disregarded.

1.3.10 Stability of Spans and Towers

(a) In calculating the stability of spans and towers, the live load on one track shall be 1200 lb per lin ft, taken without impact. On multiple-track bridges, this live load shall be on the leeward track.

1.3.11 Bracing Between Compression Members

(a) The lateral bracing of the compression chords or flanges of trusses and deck girders and between the posts of viaduct towers shall be proportioned for a transverse shear in any panel equal to 2½ percent of the total axial stress in both members in that panel, in addition to the shear from the specified lateral forces.

1.3.12 Longitudinal Force

(a) The longitudinal force from trains shall be taken as 15 percent of the live load without impact.

(b) Where the rails are continuous (either welded or bolted joints) across the entire bridge from embankment to embankment, the effective longitudinal force shall be taken as $L/1200$ (where L is the length of the bridge in feet) times the force specified in (a), but the value of $L/1200$ shall not exceed 0.50.

(c) Where the rails are not continuous (broken by a movable span, sliding rail expansion joints, or other devices) across the entire bridge from embankment to embankment, the effective longitudinal force shall be taken as the entire force specified in (a).

(d) The effective longitudinal force shall be taken on one track only and shall be distributed to the various components of the supporting structure, taking into account their relative stiffness where appropriate, and the type of bearings.

(e) The effective longitudinal force shall be assumed to be applied at the top of the supporting structure.

1.3.13 Fatigue

(a) The basic unit stresses of Art. 1.4 shall be used for the design of all members, and of all riveted, bolted and welded connections, whose design stress does not include the effect of live load.

(b) The allowable unit stresses shall be as determined below when the design stress does include the effect of live load. It should be noted that the basic unit stresses of Art. 1.4 are to be used for all riveted and bolted construction, except when there is reversal during the passage of live load. In such cases, when there is reversal, the formulas of Art. 1.3.13.1 shall be used to determine the allowable unit stresses for riveted and bolted construction. For welded construction, the formulas of Art. 1.3.13.2, which may affect the allowable unit stresses whether or not there is reversal, shall be used.

(c) The formulas to determine the applicable unit stress as given below shall be applied, with sign disregarded, to the computed stress with the greatest absolute value to determine the section of the member, or the number of fasteners or dimensions of welds in the connection. In the formulas specified,

R = 1 minus the ratio, disregarding signs, of the total range of stress to the stress with the greater absolute value. (Note that if "max." is defined as the stress with the larger numerical value, and "min." as the stress with the smaller numerical value, then R may also be defined as the ratio of min. to max., with due regard to sign.)

p_c = allowable basic unit stress in compression.

p_r = allowable basic unit stress in shear or bearing on a rivet, or in shear on a high-strength bolt.

Case I applies when the loaded length of single track is 100 ft or less.

Case II applies when the loaded length of single track is over 100 ft, or for two or more tracks of any length.

1.3.13.1 For riveted and bolted construction where the allowable stress would not be controlled by welding.

1.3.13.1.1 Base metal:

Cases I and II	(a) Tension		$\dfrac{20{,}000}{1-\dfrac{R}{2}}$ psi
		but, when R is positive	$\overline{<}$ 20,000
		and, when R is negative	$\overline{<}\ 2p_c/3R$
	(b) Compression		$\dfrac{P_c}{1-\dfrac{R}{2}}$
		but, when R is positive	$\overline{<}\ p_c$
		and, when R is negative	$\overline{<}\ 40{,}000/3R$

1.3.13.1.2 Connections:

Cases I and II	(a) Shear or bearing on rivets		$\dfrac{p_r}{1-R}$
		but, when R is positive	$\overline{<}\ p_r$
	(b) Shear on high strength bolts		$\dfrac{p_r}{1-\dfrac{R}{2}}$
		but, when R is positive	$\overline{<}\ p_r$

1.3.13.2 For welded construction.

1.3.13.2.1 Base metal not connected by or adjacent to fillet welded splices or end connections: same as for riveted and bolted construction of Art. 1.3.13.1

1.3.13.2.2 Base metal connected by or adjacent to fillet welded splices or end connections:

Case I	(a) Tension		$\dfrac{7500}{1-\dfrac{2}{3}R}$
		but, when R is positive	$\overline{<}$ 20,000
		and, when R is negative	$\overline{<}\ 2\,p_c/3R$
	(b) Compression		$\dfrac{7500}{1-\dfrac{2}{3}R}$
		but, when R is positive	$\overline{<}\ p_c$
		and, when R is negative	$\overline{<}\ \dfrac{p_c}{1-\dfrac{R}{2}}$

Case II	(a) Tension		$\dfrac{10{,}500}{1 - \dfrac{2}{3} R}$
		but, when R is positive	$\overline{<}$ 20,000
		and, when R is negative	$\overline{<}$ 2 $p_c/3R$
	(b) Compression		$\dfrac{10{,}500}{1 - \dfrac{2}{3} R}$
		but, when R is positive	$\overline{<}$ p_c
		and, when R is negative	$\overline{<} \dfrac{p_c}{1 - \dfrac{R}{2}}$

1.3.13.2.3 Connections:

Fillet welds

Case I	(a) Shear		$\dfrac{7200}{1 - \dfrac{R}{2}}$
		but, when R is positive	$\overline{<}$ 12,400
Case II	(a) Shear		$\dfrac{10{,}000}{1 - \dfrac{R}{2}}$
		but, when R is positive	$\overline{<}$ 12,400

Groove welds

Case I	(a) Tension		$\dfrac{16{,}000}{1 - \dfrac{8}{10} R}$
		but, when R is positive	$\overline{<}$ 20,000
	(b) Compression		$\dfrac{18{,}000}{1 - R}$
		but, when R is positive	$\overline{<}$ p_c
	(c) Shear		$\dfrac{9000}{1 - \dfrac{R}{2}}$
		but, when R is positive	$\overline{<}$ 12,500
Case II	(a) Tension		$\dfrac{17{,}000}{1 - \dfrac{7}{10} R}$
		but, when R is positive	$\overline{<}$ 20,000
	(b) Compression		$\dfrac{18{,}000}{1 - \dfrac{8}{10} R}$
		but, when R is positive	$\overline{<}$ p_c

(c) Shear $\dfrac{10{,}000}{1 - \dfrac{R}{2}}$

but, when R is positive $\leq 12{,}500$

1.3.14.1 Combined Stresses

Axial compression and bending.

(a) Members subject to both axial compression and bending stresses shall be proportioned to satisfy the following requirements:

When $f_a/F_a \leq 0.15$

$$\frac{f_a}{F_a} + \frac{f_{b1}}{F_{b1}} + \frac{f_{b2}}{F_{b2}} \leq 1.0$$

When $f_a/F_a > 0.15$

$$\frac{f_a}{F_a} + \frac{f_{b1}}{F_{b1}\left[1 - \dfrac{f_a}{200 \times 10^6}\left(\dfrac{k_1 l_1}{r_1}\right)^2\right]} + \frac{f_{b2}}{F_{b2}\left[1 - \dfrac{f_a}{200 \times 10^6}\left(\dfrac{k_2 l_2}{r_2}\right)^2\right]} \leq 1.0$$

and, in addition, at points braced in the planes of bending,

$$\frac{f_a}{20{,}000} + \frac{f_{b1}}{F_{b1}} + \frac{f_{b2}}{F_{b2}} \leq 1.0$$

where

F_a = axial stress that would be permitted if axial force alone existed.

F_{b1} and F_{b2} = compressive bending stress about axes 1 — 1 and 2 — 2, respectively, that would be permitted if bending alone existed.

f_a = computed axial stress.

f_{b1} and f_{b2} = computed compressive bending stress about axes 1 — 1 and 2 — 2, respectively, at the point under consideration.

$\dfrac{k_1 l_1}{r_1}$ and $\dfrac{k_2 l_2}{r_2}$ = ratios of the effective length in inches, to the radius of gyration in inches, of the compression member about axes 1 — 1 and 2 — 2, respectively.

1.3.14.2 Axial tension and bending.

(a) Members subject to both axial tension and bending stresses shall be proportioned so that the total of the axial tensile stress and the bending tensile stresses about both axes shall not exceed 20,000 psi. However, the compressive stress, if any, resulting from combining the compressive stress with respect to either axis and the minimum simultaneous axial tension stress shall not exceed the value permitted by the formula of Art. 1.4.1 for compression in the extreme fibers of flexural members.

1.3.14.3 Unit stresses for combinations of loads.

(a) The basic allowable unit stresses of Art. 1.4 as modified by the fatigue requirements of Art. 1.3.13 shall be used in the proportioning of members subject to stresses resulting from dead load, live load, impact and centrifugal force.

(b) Members, except floorbeam hangers subjected to bending, which are subject to stresses resulting from other lateral forces and/or longitudinal force in addition to the forces of (a) may be proportioned for unit stresses 25 percent greater than those permitted by (a), but the section of the member shall not be less than that required to meet the provisions of (a) alone.

1.3.15 Secondary Stresses

(a) The design and details shall be such that secondary stresses will be as small as practicable. Secondary stresses due to truss distortion usually need not be considered in any member the width of which, measured parallel to the plane of distortion, is less than 1/10 of its length. If the secondary stress exceeds 4000 psi for tension members and 3000 psi for compression members, the excess shall be treated as a primary stress.

1.3.16 Proportioning Web Members

(a) Web members shall be so proportioned that an increase in the specified live load that will increase the total unit stress in the most highly stressed chord by one-third will produce total unit stresses in the web members not in excess of one and one-third times the allowable unit stresses. Members and their connections subject to fatigue under such increased live load shall be proportioned in accordance with Art. 1.3.13, using the increased allowable unit stresses.

1.4 BASIC ALLOWABLE UNIT STRESSES

(a) The basic allowable unit stresses to be used in proportioning the parts of a bridge shall be as follows:

1.4.1 Structural Steel, Rivets, Bolts and Pins

	Pounds per Square Inch
Axial tension, structural steel, net section	20,000
Tension in floorbeam hangers, including bending, net section:	
Using rivets in end connections	14,000
Using high-strength bolts in end connections	20,000
Tension in extreme fibers of rolled shapes, girders and built sections, subject to bending, net section	20,000
Tension on A 325 and A 490 bolts including the tension resulting from prying action produced by deformation of the connected parts, gross section	36,000
Axial compression, gross section:	
For stiffeners of plate girders and splices material	20,000
For compression members centrally loaded,	
when $kl/r \leqq 25$	19,000
when $25 \leqq \frac{kl}{r} \leqq 143$	$21{,}500 - 100\,kl/r$
when $kl/r \geqq 143$	$\frac{147{,}000{,}000}{(kl/r)^2}$
where kl is the effective length, in inches, of the compression member. Under usual conditions:	
$k = \frac{7}{8}$ for members with pin-end connections.	
$k = \frac{3}{4}$ for members with riveted, bolted or welded end connections,	
and r is the least radius of gyration, in inches, of the compression member.	
Compression in extreme fibers of box-type flexural members whose proportions meet the provisions of Art. 1.6.1 and Art. 1.6.2	20,000

	Pounds per Square Inch
Compression in extreme fibers of I-type, members subjected to loading perpendicular to the web	20,000
Compression in extreme fibers of rolled shapes, plate girders and built-up flexural members having an axis of symmetry in the plane of their web (other than box-type beams and girders), the larger of the values computed by the following formulas	$20{,}000 - 0.4(l/r_y)^2$
or	$\dfrac{10{,}500{,}000}{ld/A_f}$,
but not to exceed	20,000
l = distance between points of lateral support for the compression flange, in inches.	
r_y = radius of gyration of the entire section about the axis in the plane of the web, in inches.	
A_f = area of the compression flange, in square inches, excluding any portion of the web. Refer to 1.7.2.1 (c).	
d = overall depth of the member, in inches.	
Compression in extreme fibers of channels	$\dfrac{10{,}500{,}000}{ld/A_f}$,
but not to exceed	20,000
Diagonal tension in webs of girders and rolled beams at sections where maximum shear and bending occur simultaneously	20,000
Stress in extreme fibers of pins	30,000
Shear in webs of rolled beams and plate girders, gross section	12,500
Shear in A 325 bolts	20,000
Shear in A 490 bolts	27,000
Shear in power driven rivets	13,500
Shear in hand driven rivets	11,000
Shear in pins	15,000
Bearing on power-driven rivets in single shear, and pins.	27,000
Bearing on power-driven rivets in double shear	36,000
(Rivets driven by pneumatically or electrically operated hammers are considered power-driven.)	
Bearing on A 325 and A 490 bolts	need not be considered
Bearing on milled stiffeners and other steel parts in contact	30,000
Bearing between rockers and rocker pins	13,500
Bearing on hand-driven rivets	20,000
Bearing on net area of self-lubricating bronze plates ..	2,000
Bearing on expansion rollers and rockers, pounds per lineal inch:	
For diameters up to 25 inches	$690d$
For diameters from 25 inches to 125 inches	$3450\sqrt{d}$
d = diameter of roller or rocker inches	

1.4.2 Weld Metal (based on the use of electrodes with strength at least equal to that of E60XX (ASTM A233) electrodes, and with approved types of welds and procedures)

(a) Tension or compression in groove welds .... 20,000 psi
Shear in groove welds 12,500
Shear in fillet welds, regardless of direction of applied force 12,400

1.4.3 Cast Steel

(a) For cast steel, the allowable unit stresses in compression and bearing shall be the same as those for structural steel. Other allowable unit stresses shall be ¾ of those for structural steel.

1.4.4 Masonry

(a) Bearing pressure:
Granite .... 800 psi
Sandstone and limestone 400
Concrete—0.25 of the design ultimate compressive strength. (When the strength of concrete is unknown, use 2500 psi for the design ultimate compressive strength.

1.4.5 Timber Bridge Ties

(a) Those specified in the AREA Specifications for Structural Timbers, Part 1, Chapter 7.

1.5 GENERAL DETAILS

1.5.1 Slenderness Ratio

(a) The slenderness ratio (ratio of length to least radius of gyration) shall not exceed:

100 for main compression members.
120 for wind and sway bracing in compression.
140 for single lacing.
200 for double lacing.
200 for tension members.

1.5.2 Effective Diameter of Fasteners

(a) The nominal diameter of fasteners shall be considered the effective diameter.

1.5.3 Effective Bearing Area of Rivets and Pins

(a) The effective bearing area of rivets and pins shall be the diameter multiplied by the length in bearing; except that for countersunk rivets, ½ the depth of the countersink shall be deducted from the length.

1.5.4 Thickness of Material

(a) Metal, except for fillers, shall be not less than 0.335 inch thick. Parts subject to marked corrosive influences shall be of greater thickness than otherwise or else protected against such influences.

(b) The thickness of gusset plates connecting the chords and web members of a truss shall be proportionate to the stress to be transferred but not less than ½ inch.

1.5.5 Accessibility of Parts

(a) Details shall be such that all exposed parts will be accessible for inspection, cleaning and painting. Closed sections, including closed box members, shall be completely sealed by welding.

1.5.6 Drainage of Pockets

(a) Pockets or depressions that would hold water shall have effective drain holes or else shall be filled with a suitable waterproof filler material.

1.5.7 Eccentric Connections

(a) Eccentricity between intersecting parts and between gravity axes of members intersecting at a panel point shall be avoided insofar as practicable. If eccentric connections are unavoidable, adequate provision shall be made for the bending stresses resulting from the eccentricity.

(b) For members having symmetrical cross sections, the connecting welds or fasteners shall be arranged symmetrically about the axis of the member, or proper allowance shall be made for unsymmetrical distribution of stresses.

(c) For axially-stressed angle members connected by fillet welds, the center of gravity of the connecting welds shall lie between the line of the center of gravity of the cross section of the angle and the center line of the connected leg. If the center of gravity of the connecting welds lies outside of this zone, the stress due to the eccentricity from the center of gravity of the angle must be included in the design of the connection.

1.5.8 Net Section

(a) The net section of a riveted or bolted tension member is the sum of the net sections of its component parts. The net section of a part is the product of the thickness of the part multiplied by its least net width.

(b) The net width for any chain of holes extending progressively across the part shall be obtained by deducting from the gross width the sum of the diameters of all the holes in the chain and adding, for each gage space in the chain, the quantity:

$$\frac{s^2}{4g}$$

s = pitch of any two successive holes in the chain.

g = gage of the same holes.

(c) The net section of the part is obtained from that chain which gives the least net width. However, the net width shall in no case be considered as more than 85 percent of the corresponding gross width.

(d) For angles, the gross width shall be the sum of the widths of the legs less the thickness. The gage for holes in opposite legs shall be the sum of the gages from back of angle less the thickness.

(e) For splice material, the thickness shall be only that part of the thickness of the material which has been developed by rivets or bolts beyond the section considered.

(f) The diameter of the hole shall be taken as ⅛ inch greater than the nominal diameter of the rivet or bolt.

1.5.9 Connections and Splices

(a) Connections or splices, except as noted below for milled splices in compression, shall, for main members, have a strength not less than that of the member connected; for secondary and bracing members, not less than the average of the strength of the member connected and the calculated stress therein. The requirements of Art. 1.3.13 shall be satisfied. Bracing members used as ties or struts to reduce the unsupported length of a member to which they connect need not be connected for more than the flexural strength of that otherwise unsupported member.

(b) All groove welds shall have full penetration, and shall satisfy the requirements of Art. 1.3.13.

(c) Bolted or riveted connections shall have not less than three fasteners per plane of connection.

(d) Members subject to compression only, if faced for bearing, shall be spliced on 4 sides sufficiently to hold the abutting parts true to place. The splice shall be as near a panel point as practicable and shall be designed to transmit at least ½ of the stress through the splice material. Where such members are in full milled bearing on base plates, there shall be sufficient bolted or riveted connecting material, or welding, to hold all parts securely in place.

1.5.10 Field Connections

(a) Field connections, including splices, shall be riveted or high strength bolted except that field welding may be used for minor connections not subject to live load stress, and for joining sections of deck plates, etc., which do not function as part of the load carrying structure. Welding shall not otherwise be used for field connections.

1.5.11 Development of Fillers

(a) For high-strength bolted construction, no additional bolts are necessary for the development of fillers.

(b) For riveted construction, when rivets carrying stress pass through fillers, the fillers shall be extended beyond the connected member and the extension secured by enough rivets to distribute the total stress to the member uniformly over the combined sections of the member and the fillers, except that fillers less than ¼ inch thick shall not be extended beyond the splicing material, and additional rivets are not required.

(c) For welded construction, any filler ¼ in or more in thickness shall extend beyond the edges of the splice plate and shall be welded to the part on which it is fitted with sufficient weld to transmit the splice plate stress applied at the surface of the filler as an eccentric load. The welds joining the splice plate to the filler shall be sufficient to transmit the splice plate stress and shall be long enough to avoid overstressing the filler along the toe of the weld. Any filler less than ¼ inch thick shall have its edges made flush with the edges of the splice plate and the weld size shall be the sum of the size necessary to carry the splice plate stress plus the thickness of the filler plate.

(d) For riveted construction, eccentricity must be considered on short, thick fillers.

1.5.12 Combinations of Dissimilar Types of Connections

(a) Rivets and high-strength bolts in the same connection plane may be considered as sharing the stress.

(b) Welds in the same connection plane with rivets and/or bolts shall not be considered as sharing the stress.

(c) When two or more of the general types of weld (groove, fillet, slot) are combined in a single connection, the effective capacity of each shall be separately computed with reference to the axis of the group in order to determine the allowable capacity of the combination.

1.5.13 Sealing

(a) When two or more plates or shapes are in contact, there shall be provision made for sealing their edges for protection against the entrance of moisture.

(b) For riveted and bolted members, sealing shall be accomplished by limiting the spacing of the fasteners connecting component parts. The pitch on a single line adjacent to a free edge of an outside plate or shape shall not exceed $4 + 4t$, t being the thickness of the thinnest outside plate or shape, nor 7 inches. If there is a second line of fasteners uniformly staggered with those in the line adjacent to the free edge, at a gage, g, less than $1\frac{1}{2} + 4t$ therefrom, the staggered pitch of the fasteners in such two lines shall not exceed $4 + 4t - \frac{3}{4}g$, nor $7 - \frac{3}{4}g$, but need not be less than one-half the requirement for a single line.

(c) For welded members, sealing shall be accomplished by the use of continuous welds at exposed edges of contact surfaces of such dimensions and made by such procedure as will ensure soundness of the weld throughout. Note requirements for minimum size fillet welds in Art. 1.10.5 (a).

1.5.14 Connections of Components of Built-Up Members

(a) When two or more plates or shapes are in contact, they shall be connected sufficiently to make them act in unison.

(b) For riveted and bolted members, stitch fasteners shall be used to make component parts of the member act in unison. The pitch of stitch fasteners in compression members on any single line shall not exceed $12t$, t being the thickness of the thinnest outside plate or shape, except that, if the fasteners on adjacent lines are staggered and the gage, g, between the line under consideration and the farther adjacent line is less than $24t$, the staggered pitch in such two lines shall not exceed $12t$, nor $15t - \frac{3}{8}g$. The gage between adjacent lines of such stitch rivets shall not exceed $24t$. At the ends of compression members, the pitch of stitch fasteners on any single line in the direction of stress shall not exceed 4 times the diameter of the fasteners for a distance equal to $1\frac{1}{2}$ times the width of the member. In tension members, the pitch of stitch fasteners shall not exceed twice that specified for compression members, and the gage shall not exceed that specified for compression members.

(c) For welded members, lines of continuous longitudinal welds, and when required, lines of continuous fillet welds in holes or slots, shall be used to make the component parts of the member act in unison. Continuous fillet welds in holes or slots shall be used, in addition to the continuous longitudinal welds, when the distance between these continuous longitudinal welds exceeds $24t$. The clear spacing between these holes or slots, measured parallel to the longitudinal axis of the member, shall not exceed $10t$, nor 12 inches for compression members, nor $14t$, nor 12 inches for tension members.

(d) The requirements of Articles 1.5.13 and 1.5.14 are not additive, but both must be satisfied by the detail used.

1.6 MEMBERS STRESSED PRIMARILY IN AXIAL TENSION OR COMPRESSION

1.6.1 Compression Members

(a) Compression members shall be so designed that the main elements of the section will be connected directly to the gusset plates, pins, or other members.

(b) In members consisting of segments connected by lacing or by solid cover plates, the thickness of the web plate shall not be less than

$$\frac{b}{32\sqrt{\frac{p}{f}}}, \qquad \sqrt{\frac{p}{f}} \text{ not to exceed } 2$$

and the thickness of the cover plate shall not be less than

$$\frac{b}{40\sqrt{\frac{p}{f}}}, \qquad \sqrt{\frac{p}{f}} \text{ not to exceed } 2$$

where b = unsupported distance between the nearest lines of fasteners or welds, or between the roots of rolled flanges

p = basic allowable unit stress determined by the kl/r of the member and the applicable formula of Art. 1.3.13

f = actual average unit stress in compression

(c) For the thickness requirements for perforated cover plates, see Art. 1.6.4.3.

1.6.2 Outstanding Elements in Compression

(a) The width of outstanding elements of members in compression shall not exceed the following, where t is the thickness of the element:

(1) Legs of angles or flanges of beams or tees:
$10t$ for stringers and girders where ties rest on the flange.
$12t$ for main members carrying axial stress, and for stringers and girders where ties do not rest on the flange.
$14t$ for bracing and other secondary members.

(2) Plates: $12t$.

(3) Stems of tees: $16t$.

(b) The width of plates shall be taken from the free edge to the first row of fasteners or welds; the width of legs of angles, and of the stems of tees, shall be taken as the full nominal dimension; the width of flanges of beams and tees shall be taken from the free edge to the fillet.

(c) When a projecting element exceeds the width-to-thickness ratio prescribed above, but would conform to same and would satisfy the stress requirements with a portion of its width considered as removed, the member will be acceptable.

1.6.3 Stay Plates

(a) On the open sides of compression members, the segments shall be connected by lacing bars and there shall be stay plates as near each end as practicable. There shall be stay plates at intermediate points where the lacing is interrupted. In main members, the length of the end stay plates shall be not less than 1¼ times the distance between the lines of connections to the outer flanges. The length of intermediate stay plates shall be not less than ¾ of that distance.

(b) The segments of tension members composed of shapes shall be stayed together. The length of the stay plates shall be not less than 2/3 of the lengths specified for stay plates on compression members.

(c) The thickness of stay plates shall be not less than 1/50 of the distance between the lines of connections to the outer flanges for main members, or 1/60 of that distance for bracing members.

(d) For riveted or bolted stay plates, the fasteners shall be spaced not more than four diameters on centers, and not less than 3 fasteners shall be used in a line. For welded stay plates, $\frac{5}{16}$ inch minimum continuous fillet welds shall be used along their longitudinal edges.

1.6.4 Lacing and Perforated Cover Plates for Tension and Compression Members

1.6.4.1 Shearing force.

(a) The shearing force normal to the member in the planes of lacing or continuous plates with or without perforations shall be assumed divided equally between all such parallel planes. The shearing force shall include any due to the weight of the member and to other forces and, for compression members, also that obtained by the following formula:

$$V = \frac{P}{100}\left(\frac{100}{l/r + 10} + \frac{l/r}{100}\right)$$

V = shearing force

P = allowable compressive axial load on member

l = length of member in inches

r = radius of gyration of section about the axis perpendicular to the plane of lacing or plates, in inches

1.6.4.2 Lacing

(a) Lacing bars of compression members shall be so spaced that the slenderness ratio of the portion of the flange included between lacing-bar connections will not be more than 40 nor more than ⅔ of the slenderness ratio of the member.

(b) The section of the lacing bars shall be determined by the formula for axial compression in which l is taken as the distance along the bar between its connections to the main segments for single lacing, and as 70 percent of that distance for double lacing.

(c) If the distance across the member between connection lines in the flanges is more than 15 inches and a bar not over 3½ inches wide is used, the lacing shall be double and connected at the intersections.

(d) The angle between the lacing bars and the axis of the member shall be approximately 45° for double lacing and 60° for single lacing.

(e) Lacing bars may be shapes or flat bars. For main members, the minimum thickness of flat bars shall be 1/40 of the distance along the bar between its connections for single lacing, and 1/60 for double lacing. For bracing members the limits shall be 1/50 for single lacing and 1/75 for double lacing.

(f) For riveted or bolted construction, the diameter of the fasteners in lacing bars shall not exceed ⅓ the width of the bar. There shall be at least two fasteners in each end of lacing bars fastened to flanges more than 5 inches in width.

(g) For welded construction, fillet welds comparable in strength to that furnished for riveted or bolted construction shall be used.

1.6.4.3 Perforated cover plates.

(a) Perforations shall be ovaloid or elliptical.

(b) The length of perforation shall be not more than twice its width. Also, for compression members the ratio of the length of perforation to the radius of gyration of the half-member at the center of perforation about its own axis shall be not more than 20 and not more than one-third of the slenderness ratio of the member about its axis perpendicular to the perforation.

(c) The clear distance between perforations shall be not less than the distance between the nearer lines of connections.

(d) For tension members the thickness of the perforated plate shall be not less than 1/50 of the distance between the nearer lines of connections. For compression members the thickness shall be not less than 1/50 of such distance and not less than 1/12 of the distance from such a line of connections to the edge of the perforation at the center of perforation. Also, for all members, the thickness shall be not less than that required by the formula:

$$t = \frac{3cU}{2vh(c-a)}$$

t = thickness of plate

c = spacing of perforations

U = maximum transverse shearing force in the plane of the plate

v = allowable unit shear specified for plate girder webs

h = width of plate

a = length of perforation

$c-a$ = distance between perforations

(e) When the plate is spliced for transfer of stress, the clear distance between the end perforation and the end of the plate shall be not less than the distance between the nearer lines of connections, except that one-half such distance may be used for compression members which are faced for bearing. When the plate is not spliced for transfer of stress, an open perforation may be used at the end of the plate provided that its length does not exceed one-half the distance between the nearer lines of connections.

(f) The gross section of the plate through the perforation for compression members and the net section of the plate through the perforation for tension members shall be considered as a part of the area of the member.

1.6.5 Effective Sections of Angles or Tees

(a) If angles or tees in tension are so connected that bending cannot occur in any direction, the effective section shall be the net section of the member. If such members are connected on one side of a gusset plate, the effective section shall be the net section of the connected element plus ½ the section of the unconnected element.

1.7 MEMBERS STRESSED PRIMARILY IN BENDING

1.7.1 Proportioning Girders and Beams

(a) Plate girders, I-beams, and other members subject to bending that produces tension on one face, shall be proportioned by the moment-of-inertia method. The neutral axis shall be taken along the center of gravity of the gross section. The tensile stress shall be computed from the moment of inertia of the entire net section and the compressive stress from the moment of inertia of the entire gross section.

(b) If the compression flange is not fully supported laterally, the flexural member shall be so proportioned that the ratio of the distance between points of attachment of lateral supports and the radius of gyration of the entire section about the axis in the plane of the web shall not exceed 157.

1.7.2 Flange Sections

1.7.2.1 Riveted or bolted construction

(a) Flanges of plate girders preferably shall be made without cover plates or side plates.

(b) When cover plates are used, at least one plate of each flange shall extend the full length of the girder or beam. Other flange plates shall extend far enough to develop the capacity of the plate beyond the theoretical end.

(c) The area of the compression flange A_f used in the determination of the allowable unit stress in flexural compression as specified in Art. 1.4.1 shall be as determined by the formula $A_f = 5Ar_{y2}/b_2$ where:

A = area of entire flexural member section in square inches

r_y = radius of gyration of the entire flexural member section about the axis of the web in inches

b = maximum width of compression flange in inches

1.7.2.2 Welded construction

(a) Flanges of welded plate girders shall be made with one plate in each flange, i.e., without cover plates. Side plates shall not be used in welded construction. The thickness and width of the flange plate may be varied by butt welding parts of different thickness or width with transitions conforming to the requirements of Art. 1.10.2.

(b) Not more than one cover plate may be used on each flange of a rolled beam. Such cover plates shall be full length and of uniform thickness and width, and shall be connected to the flange of the rolled beam with continuous fillet welds of sufficient strength to transmit the horizontal shear into the cover plate. The thickness of a cover plate shall not be greater than 1½ times the thickness of the flange to which it is attached.

1.7.3 Thickness of Web Plates

(a) The thickness of the webs of plate girders shall be not less than 1/170 of the clear distance between the flanges, except that if the extreme fiber stress in the compression flange is less than that allowable, the denominator 170 may be multiplied by the factor $\sqrt{p/f}$.

p = the allowable extreme fiber stress.

f = the extreme fiber stress in the compression flange.

1.7.4 Flange-To-Web Connection of Plate Girders

(a) The flange angles of riveted or bolted plate girders shall be connected to the web with enough rivets or bolts to transmit to the flange section the horizontal shear at any point together with any load that is applied directly on the flange.

Where the ties rest on the flange, one wheel load, including 80 percent impact, shall be assumed to be distributed over 3 ft. On ballasted deck girders, the wheel load, including 80 percent impact, shall be assumed to be distributed over 5 ft.

(b) The flange plates of welded plate girders shall be connected to the web plate with continuous, full penetration tee welds.

1.7.5 Flange Splices

(a) Flange members that are field spliced, or that are shop spliced by riveting and/or bolting, shall be covered by extra material not less in section than the member spliced. There shall be enough fasteners on each side of the splice to transmit to the splice material the stress value of the part cut. Flange angles shall be spliced with angles. No two elements in the same flange shall be spliced at the same cross section.

(b) In welded construction, flange members which are shop spliced may be spliced as required in (a) for field splicing, or may be spliced by welding.

(c) Welded shop splices shall be full penetration groove welds. They shall preferably be made in the same cross section except when made before webs and flanges are joined to each other they may be located in the same or different cross sections.

(d) Welded shop splices of rolled beams shall be full penetration groove welds at the same cross section, and must be made without cope holes, i.e., the entire cross section must be welded.

1.7.6 Web Splices

(a) Splices in the webs of plate girders or rolled beams shall be designed to meet both of the following conditions:

1. Full shear strength of the web, gross section.
2. The combination of the full moment strength of the web, net section, with the maximum shear that can occur at the section where the splice is located.

(b) Shop or field web splices in riveted or bolted construction and field web splices in welded construction shall be made using splice plates on each side of the web, of the strength required by (a). The net amount of inertia of these web splice plates shall not be less than that of the web.

(c) Shop web splices in welded construction may be made as indicated in (b), or may be welded. Welded shop splices shall be full penetration groove welds, and the entire cross section shall be welded.

1.7.7 Stiffeners at Points of Bearing

(a) Stiffeners shall be placed in pairs at end bearings of plate girders and beams, and at points of bearing of concentrated loads. They shall extend as nearly as practicable to the edges of the flange to give effective distribution and shall be connected to the web by enough rivets, bolts or welds to transmit the load. When angle stiffeners are used, they shall not be crimped. When plate stiffeners are used, they shall be clipped at 45° at upper and lower ends to clear fillet of flange angle or weld connecting flange plate to web, as applicable. Only that part of the outstanding leg of an angle stiffener, or that part outside the corner clip of a plate stiffener, which is in contact with the flange angle or flange plate, shall be considered effective in bearing.

1.7.8 Intermediate Stiffeners

(a) If the depth of the web between the flanges or side plates of a riveted, bolted or welded plate girder exceeds 60 times its thickness, it shall be stiffened by pairs (except as noted below in (c) of angles riveted or bolted, or of plates welded, to the web. The clear distance between stiffeners shall not exceed 72 inches or that given by the formula:

$$d = \frac{10500\, t}{\sqrt{S}}$$

d = clear distance between stiffeners, in inches.

t = thickness of web, in inches.

S = unit shearing stress, gross section, in web at point considered.

(b) The width of the outstanding leg of each angle, or the width of the welded stiffener plate, shall be not more than 16 times its thickness and not less than 2 inches plus 1/30 of the depth of the girder.

(c) Stiffeners on one side of a plate girder may be used, provided they have the same stiffness as the minimum acceptable pairs of angles or plates. They shall be connected to the outstanding portion of the compression flange.

1.8 FLOOR MEMBERS IN TRUSSES AND GIRDER SPANS

1.8.1 End Floorbeams

(a) Spans with floor systems shall have end floorbeams unless otherwise specified. Except where other means are provided, end floorbeams shall be proportioned for lifting the span without exceeding the design unit stresses more than 50 per cent.

1.8.2 Floorbeams and Floorbeam Hangers

(a) Floorbeams preferably shall be square to the girders or trusses.

(b) The main material of floorbeam hangers shall not be coped or notched. Built-up hangers shall have solid or perforated web plates, or lacing. The thickness of the main material of floorbeam hangers shall not be less than ½ inch.

1.8.3 End Connections of Floor Members

(a) Beams in solid floor construction, stringers and floorbeams shall have end connection angles to ensure the necessary flexibility in the connection. Welding shall not be used to connect the flexing leg.

(b) The flexing legs of the connection angles shall be not less than 4 inches in width and ½ inch in finished thickness.

(c) For stringers, the gage of the flexing legs of the connection angles over the top ⅓ of the stringer depth shall be not less than the quantity. $\sqrt{\frac{lt}{8}}$

l = length of stringer span, in inches

t = thickness of angle, in inches

1.9 RIVETED AND BOLTED CONSTRUCTION

1.9.1 Pitch and Gage of Fasteners

(a) The pitch of fasteners is the distance, in inches, between centers of adjacent fasteners, measured along one or more lines of fasteners. The gage of fasteners is the distance, in inches, between adjacent lines of fasteners, or the distance from the back of angle or other shape to the first line of fasteners.

1.9.2 Grip of Rivets

(a) If the grip of rivets carrying calculated stress exceeds 4½ times the diameter, the number of rivets shall be increased at least 1 percent for each additional $\frac{1}{16}$ inch of grip. If the grip equals or exceeds 6 times the nominal diameter, the body shall be tapered from the head for a distance not less than 3.42 times the nominal diameter, but not more than 4¾ inches. The body diameter at the head shall be $\frac{1}{32}$ inch greater and where not tapered, $\frac{1}{64}$ inch less than the nominal diameter.

1.9.3 Minimum Spacing of Fasteners

(a) The distance between centers of fasteners shall be not less than 3 times the diameter of the fasteners.

1.9.4 Edge Distance of Fasteners

(a) The distance from the center of a fastener to a sheared edge shall not be less than 1¾ times the diameter, nor to a rolled or planed edge less than 1½ times the diameter, except in flanges of beams and channels, where the minimum distance may be 1¼ times the diameter.

(b) The distance from the free edge of an outside plate or shape to the first line of fasteners shall not exceed 1½ + $4t$, nor 6 inches. t = thickness, in inches, of the plate or shape.

1.9.5 Sizes of Fasteners in Angles

(a) In angles, the size of which is determined by calculated stress, the diameter of the fasteners shall not exceed ¼ of the width of the leg in which they occur. In angles, the size of which is not so determined, 1-inch fasteners may be used in 3½-inch legs, ⅞-inch fasteners in 3-inch legs, and ¾-inch fasteners in 2½-inch legs.

1.9.6 Extra Rivets in Indirect Splices

(a) If splice plates are not in direct contact with the parts which they connect, for riveted construction only, there shall be rivets on each side of the joint in excess of the number required in the case of direct contact, to the extent of two extra lines for each intervening plate. (If high-strength bolts are used, no additional bolts need be added for indirect splices, nor for connections or splices with fillers.)

1.10 WELDED CONSTRUCTION

1.10.1 Effective Area of Weld Metal

(a) Groove welds. The effective area shall be the effective weld length multiplied by the effective throat thickness.

1. The effective weld length for any groove weld, square or skewed, shall be the width of the part joined, perpendicular to the direction of stress.
2. The effective throat thickness shall be the thickness of the thinner piece of base metal joined. (No increase is permitted for weld reinforcement.)

(b) Fillet welds. The effective area shall be the effective weld length multiplied by the effective throat thickness.

1. The effective length of a straight fillet weld shall be the overall length of the full-size fillet including end returns.
2. The effective length of a curved fillet weld shall be the length of the line generated by the centerpoint of the effective throat thickness.
3. The effective throat thickness shall be the shortest distance from the root of the diagrammatic weld to the face.

1.10.2 Transition of Thicknesses or Widths in Welded Butt Joints

(a) When butt joints subject to any tensile stress are used to join material of different thicknesses or widths, there shall be smooth transition between offset surfaces or edges at a slope of not more than 1 in 2½ with the surface or edge of either part. The transition of thickness may be accomplished by sloping weld faces, by chamfering the thicker part or by a combination of the two methods.

(b) Butt joints subject only to shear or compressive stress shall be made with the above specified smooth transition when the offset between surfaces at either side of the joint is greater than the thickness of the thinner part connected. When the offset is equal to or less than this amount, the face of the weld shall be sloped 1 in 2½ from the surface of the thinner part or shall be sloped to the surface of the thicker part if this requires a lesser slope.

(c) Joints made between plates of different widths, but with a common longitudinal axis of symmetry, may be considered the same as those made between plates of equal widths if the width of the wider plate is reduced to that of the narrower plate at the joint between the two plates by symmetrical curved transition cuts with two foot radii, tangent to the edge of the narrower plate at the joint.

1.10.3 Prohibited Types of Joints and Welds

(a) Prohibited types of joints and welds are:

(1) Butt joints not fully welded throughout their cross section.
(2) Groove welds made from one side only, except in secondary or non-stress carrying members and for shoes, etc., unless made by a process acceptable to the engineer which will ensure that the resulting weld is a full penetration groove weld.
(3) Intermittent groove welds.
(4) Intermittent fillet welds.
(5) Plug or slot welds. (This does not prohibit the use of fillet welds in holes or slots.)

1.10.4 Groove Welds

(a) Groove welds shall be designed on the basis of the allowable unit stresses of Art. 1.3.13.2.3 except that basic unit stresses of Art. 1.4.1 may be used with the same reductions for fatigue applicable to main members of Art. 1.3.13.2.1, provided that:

(1) The parts joined are of equal thickness.
(2) The parts joined are of equal width or have transition in widths conforming to Art. 1.10.2.
(3) The weld is finished smooth and flush with the base metal on all surfaces by grinding in the direction of applied stress, leaving surfaces free from depressions. Chipping may be used provided it is followed by such grinding.

(4) Weld soundness is established by radiographic or ultrasonic inspection as required by Art. 2.5.5.

1.10.5 Fillet Welds

(a) The minimum size of fillet welds shall be such as to ensure against cracking due to contraction on cooling, and shall be reviewed and approved by the engineer. Due consideration shall be given to the thickness of the material being joined and the welding procedure used. The minimum fillet weld sizes, except when used to reinforce groove welds, which are acceptable without additional proof of satisfactory procedure and freedom from cracking shall be as follows:

Material Thickness of Thicker Part Joined Inch	*Minimum Size* of Fillet Weld Inch*
To ½ inch, incl.	$\frac{3}{16}$
Over ½ to ¾	¼
Over ¾ to 1½	$\frac{5}{16}$
Over 1½ to 2¼	⅜
Over 2¼ to 6	½
Over 6	⅝

* Except that the weld size need not exceed the thickness of the thinner part joined.

(b) The maximum effective size of a fillet weld that may be assumed in the design of a connection shall be such that the stresses in the adjacent base material do not exceed the values in Art. 1.4.

(c) The maximum size fillet weld that may be used along edges of connected parts shall be:

(1) Along edges of material less than ¼ inch thick, the maximum size may be equal to the thickness of the material.

(2) Along edges of material ¼ inch or more in thickness, the maximum size shall be $\frac{1}{16}$ inch less than the thickness of the material, unless the weld is especially designated on the drawings to be built out to obtain full throat thickness.

(d) The minimum effective length of a fillet weld shall be four times its size and in no case less than 1½ inches.

(e) Fillet welds which resist a tensile force which is not parallel to the axis of the weld, or which are proportioned to resist repeated stress shall not terminate at corners of parts or members but shall be returned continuously, full size, around the corner for a length equal to twice the weld size where such return can be made in the same plane. End returns shall be indicated on design and detail drawings.

(f) Fillet welds may be used to join two adjacent surfaces not meeting at a right angle provided that the angle between such surfaces is not less than 60°.

(g) Fillet welds in holes or slots may be used to transmit shear in lap joints or to prevent buckling or separation of lapped parts. Fillet welds in a hole or slot shall not overlap.

1.10.6 Shrinkage of Welded Joints

(a) Joints shall be designed so as to minimize, insofar as practicable, stresses due to the contraction of the weld metal and adjacent base metal upon cooling.

1.10.7 Groove Welded Joints

(a) The detail configuration of groove welded joints shall be shown or indicated by standard symbols or sketches on design and detail drawings, and shall be reviewed and approved by the engineer.

1.10.8 Welded Tee and Corner Joints

(a) Tee and corner joints that are to be subjected to bending about an axis parallel to the joint shall have their welds arranged to avoid concentration of tensile stress at the root of the weld.

1.10.9 Welded Lap Joints

(a) The minimum overlap of parts in stress carrying lap joints shall be 5 times the thickness of the thinner part. Unless lateral deflection of the parts is prevented, they shall be connected by at least two transverse lines of fillet welds, or by two or more longitudinal fillet welds.

(b) If longitudinal fillet welds are used alone in lap joints of end connections, the length of each fillet weld shall not be less than the perpendicular distance between them. The transverse spacing of the welds shall not exceed 16 times the thickness of the thinner part connected unless suitable provision is made to prevent buckling or separation of the parts. The longitudinal fillet welds may be either at the edges of the member or in slots.

(c) When fillet welds in holes or slots are used, the clear distance from the edge of the hole or slot to the adjacent edge of the part containing it, measured perpendicular to the direction of the stress, shall not be less than 5 times the thickness of the part nor less than 2 times the width of the hole or slot. The strength of the part shall be determined from the critical net section of the base material.

1.10.10 Welded Attachments to Tension Members and Elements

(a) Brackets, clips, gussets, stiffeners and other detail material shall not be welded to members or parts subjected to tensile stress from live load unless the maximum tensile stress at point of attachment does not exceed that which is allowed by Art. 1.3.13.2.2.

1.11 BRACING

1.11.1 Bracing of Top Flanges of Through Girders

(a) The top flanges of through plate girders shall be braced at the panel points by brackets with web plates. The brackets shall extend to the top flange of the main girder and be as wide as the clearance will allow. They shall be attached securely to a stiffener on the girder and to the top flange of the floorbeam. On solid floor bridges the brackets shall be not more than 12 ft apart.

1.11.2 Lateral Bracing

(a) There shall be bottom lateral bracing in all spans except deck spans less than 50 ft long. There shall be top lateral bracing in all deck spans and in through spans that have enough head room.

(b) If the construction of the floor is such as to afford the specified lateral resistance, the floor shall be taken as the lateral bracing required in its plane.

(c) There shall be not less than three fasteners, or comparable welding, in each connected plane.

(d) If the bracing is a double system and the members meet the requirements for both tension and compression members, both systems may be considered effective simultaneously.

1.11.3 Portal and Sway Bracing

(a) In through truss spans there shall be portal bracing, with knee braces, as deep as the clearance will allow. There shall be sway bracing at the intermediate panel points if the trusses are high enough to allow a depth of 6 ft or more for such bracing. If they are not high enough to allow that depth, the top lateral struts shall be of the same depth as the chord, and there shall be knee braces as deep as the clearance will allow.

(b) In deck truss spans there shall be sway bracing at the panel points. The top lateral forces shall be carried to the supports by means of a complete system of bracing.

1.11.4 Cross Frames and Diaphragms

(a) Longitudinal girders or beams having depth greater than 3 feet 6 inches and spaced more than 4 ft on centers shall be braced with crossframes. The angle of crossframe diagonals with the vertical shall not exceed 60°.

(b) Longitudinal girders or beams not requiring crossframes shall be braced with I-shaped diaphragms which are as deep as the depth of the girders or beams will permit. Such diaphragms shall be connected to the girder or beam webs by means of double angles, if riveted or bolted, or their equivalent if welded.

(c) Crossframes or diaphragms shall be used at the ends of spans (except where the girders or beams are framed into floorbeams), and shall be proportioned for centrifugal and lateral forces.

(d) A crossframe or diaphragm shall be used at the center of the span when the length of longitudinal girders or beams exceeds the allowable spacing of crossframes or diaphragms.

(e) In open deck construction, crossframes or diaphragms shall be used at intervals not exceeding 18 ft.

(f) Where plate, timber or precast concrete decking is utilized in ballasted deck construction, crossframes or diaphragms without top lateral bracing shall be used at intervals not exceeding 12 ft; or with top lateral bracing, at intervals not exceeding 18 ft.

(g) Where poured-in-place concrete decking is used in ballasted deck construction, crossframes or diaphragms shall be used at intervals not exceeding 24 ft. For girders or beams up to 4 feet 6 inches deep, concrete diaphragms with reinforcement extending through the girders or beams may be used instead of steel diaphragms.

(h) Where ballast and track are carried on transverse beams without stringers, the beams shall be connected with at least one line of longitudinal diaphragms per track.

1.11.5 Bracing of Viaduct Towers and Bents

(a) The bracing of bents and towers shall consist of double systems of diagonals with struts at caps and bases and at intermediate panel points. In double track towers there shall be horizontal bracing at the top of the tower to transmit horizontal forces.

(b) The bottom struts shall be proportioned for either the calculated stresses or a stress in tension or compression equal to ¼ of the dead-load reaction on 1 pedestal, whichever is greater. The column bearings shall be designed to allow for the expansion and contraction of the tower bracing.

1.12 PINS AND PIN-CONNECTED MEMBERS

1.12.1 Pins

(a) Pins more than 7 inches in diameter shall be forged and annealed.

(b) In pins more than 9 inches in diameter, there shall be a hole not less than 2 inches in diameter bored longitudinally on the center line.

(c) The turned bodies of pins shall be long enough to extend at the ends ¼ inch beyond the outside faces of the parts connected. The pins shall be secured by recessed pin nuts or by solid nuts and washers. If the pins are bored, through rods with cap washers may be used. The screw ends shall be long enough to allow burring the threads.

1.12.2 Section at Pin Holes

(a) The net section beyond the pin hole, parallel with the axis of the member, shall be not less than the required net section of the member. The net section through the pin hole, transverse to the axis of the member, shall be at least 40 percent greater than the required net section of the member. The ratio of the transverse net width through the pin hole to the thickness of the segment shall not be more than eight.

1.12.3 Reinforcing Plates at Pin Holes

(a) Where necessary for the required section or bearing area, the section at pin holes shall be increased on each segment by plates so arranged as to reduce the eccentricity of the segment to a minimum. One plate on each side shall be as wide as the outstanding flanges will allow. At least one full width plate on each segment shall extend to the far edge of the stay plate, and the others not less than 6 inches beyond the near edge. These plates shall be connected adequately to transmit the bearing pressure and so arranged as to distribute it uniformly over the full section.

1.12.4 Forked Ends of Compression Members

(a) Forked ends of compression members will be permitted only where unavoidable. There shall be enough pin plates on forked ends to make the section of each jaw equal to that of the member. The pin plates shall be long enough to develop the pin plate beyond the near edge of the stay plate, but not less than the length required by Art. 1.12.3.

1.13 END BEARINGS AND PROVISION FOR EXPANSION

1.13.1 Expansion

(a) The design shall be such as to allow for the changes in length of the spans resulting from changes in temperature, at the rate of 1 inch in 100 feet. Provision shall be made for changes in length of the span resulting from the live-load stresses. In spans more than 300 ft long, allowance shall be made for the expansion in the floor system.

1.13.2 End Bearings

(a) In spans more than 70 ft long, there shall be hinged bearings at both ends and rollers or rockers at the expansion end. Shorter spans shall be designed to slide on bearings with smooth surfaces. Self-lubricating bronze bearing plates, with a coefficient of friction not more than 0.10, may be used to provide expansion instead of rollers and rockers. These plates shall be not less than ½ inch thick.

(b) Bearings and ends of spans shall be secured against lateral and vertical movement.

(c) End bearings on masonry preferably shall be raised above the bridge seat by metal pedestals or bolsters.

1.13.3 Shoes and Pedestals

(a) Shoes and pedestals shall be designed on the assumption that the vertical load is distributed uniformly over the entire bearing surface. They shall be made of cast steel, or may be built up by welding rolled steel and/or cast steel elements together.

(b) No part of a cast steel shoe, and no load carrying part of a welded shoe, shall be less than 1 inch in thickness.

(c) In a welded shoe, the vertical load shall be carried directly by contact bearing between elements. Diaphragms shall be provided between web surfaces to ensure stability of component parts.

(d) The difference in width or length between top and bottom bearing surfaces shall not exceed twice the vertical distance between them. For hinged bearings, the vertical distance shall be measured from the center line of pin.

1.13.4 Rockers or Rollers

(a) Rockers shall be used in preference to rollers where conditions permit. The upper surface of rockers shall have a pin or cylindrical bearing. The lower portion at the nominal center line of bearing shall be not less than 1½ inches thick, and the lower surface shall be cylindrical with its center of rotation at the center of rotation of the upper bearing surface. The effective length of rocker for calculating line bearing stress shall be not greater than the length of the upper bearing surface plus the distance from the lower surface to the upper bearing surface. There shall be sufficient web material between upper and lower portion of rocker to insure uniform distribution of load over the effective length of rocker. The rocker shall be doweled to the base plate.

(b) Rollers may be either cylindrical or segmental and shall be not less than 6 inches in diameter. They shall be secured to insure parallelism and doweled to the upper and lower plates. The roller nest shall be so designed that the parts may be readily cleaned.

1.13.5 Base and Masonry Plates

(a) Base and masonry plates shall be designed on the assumption that the vertical load is distributed uniformly over a bearing area with effective length and width as defined in (b), except for eccentricity from rocker travel.

(b) The effective length of the bearing area shall be not greater than the effective length of the rocker as defined in Art. 1.13.4 (a), or the length of the roller plus 2 times the thickness of the base plate. The effective width of the bearing area shall be not greater than 4 times the thickness of base plate for rockers, and the distance between end rollers plus 4 times the thickness of base plate for rollers.

(c) For spans designed to slide on bearings with smooth surfaces without hinges, the distance from center line of bearing to edge of masonry plate, measured parallel with the track, shall be not more than 2 times the thickness of the plate plus 4 inches.

1.13.6 Inclined Bearings

(a) For spans on an inclined grade and without hinged bearings, the sole plates shall be beveled so that the masonry surfaces may be made level.

1.13.7 Anchor Bolts

(a) Anchor bolts shall be not less than 1¼ inches in diameter. There shall be washers under the nuts. Anchor bolt holes in pedestals and sole plates shall be ⅜ inch larger in diameter than the bolts. At expansion points the holes in the sole plates shall be slotted.

(b) Anchor bolts that do not take uplift shall extend 12 inches into the masonry. Those that do take uplift shall be designed to engage a substantial mass of masonry the weight of which is at least 1½ times the uplift.

2.0 FABRICATION

2.1 GENERAL

2.1.1 Quality of Workmanship

(a) The workmanship and finish shall be equal to the best general practice in modern bridge shops.

2.1.2 Material Orders and Shipping Statements

(a) The contractor shall furnish to the engineer as many copies of material orders and shipping statements as the engineer may require. The weights of the individual members shall be shown on the statements.

2.1.3 Notice of Beginning Work

(a) The contractor shall give the engineer ample notice of the beginning of rolling in the mill and of work in the shop, in order that inspection may be provided. Material shall not be rolled nor work done in the shop before the engineer has been so notified.

2.1.4 Storage of Material

(a) Structural material, either plain or fabricated, shall be stored at the bridge shop above the ground upon platforms, skids, or other supports. It shall be kept free from dirt, grease and other foreign matter, and shall be protected as far as practicable from corrosion.

2.1.5 Straightening Material

(a) Rolled material, before being laid off or worked, shall be straight within the tolerances allowed by ASTM Specification A 6. If straightening is necessary, it shall be done by methods which will not adversely affect the behavior of the material.

2.1.6 Flame Cutting

(a) The steels and wrought iron covered by these specifications may be flame-cut, provided that a smooth surface free from cracks and notches is secured and provided that an accurate profile is secured by the use of a mechanical guide. Free-hand flame-cutting shall be done only when specifically approved by the engineer.

(b) The cutting flame shall be so adjusted and manipulated as to avoid cutting inside the prescribed lines. Roughness of cut surfaces shall not be greater than that defined by the United States of America Standard Institute surface roughness value of 1000 (USASI B46.1, Surface Texture). The procedure described below may be used to correct roughness exceeding this value or occasional notches or gouges. Roughness exceeding this value and occasional notches or gouges not more than $\frac{3}{16}$ inch deep, on otherwise satisfactory surfaces, shall be removed by machining or grinding. Cut surfaces and edges shall be left free of adhering slag. Corrections of defects shall be faired to the flame-cut surface with a slope not exceeding 1 in 10. Defects of flame-cut edges shall not be repaired by welding except with the express approval of the engineer for occasional notches or gouges less than $\frac{3}{8}$ inch deep. Such weld repair shall be done by a procedure acceptable to the engineer which will ensure sound metal, free from cracks, and with a workmanlike finish.

(c) Re-entrant corners shall be filleted to a radius of not less than $\frac{3}{4}$ inch. The fillet and its contiguous cuts shall meet without offset or cutting past the point of tangency.

2.1.7 Straightness and Dimensional Tolerances

(a) Fabricated members and parts of members shall be straight, true to line and free from twists and bends. In determining acceptability under this general requirement, the tolerances stated hereinafter have been established to apply primarily to welded members. It is expected that riveted and bolted members will be well within these specified tolerances, but in no case shall they be permitted to exceed them.

Deviation from detailed length for floorbeams and for stringers with facing connections, and for members with milled-to-bear ends . . . . $\pm \frac{1}{32}$ inch maximum

Deviation from straightness of compression members:

Lengths of 45 ft and under:

$$\frac{1}{8}\text{ inch} \times \frac{\text{No. of ft of total length}}{10}$$

Lengths over 45 ft:

$$\frac{3}{8}\text{ inch} + \frac{1}{8}\text{ inch} \times \frac{\text{No. of ft of total length} - 45}{10}$$

Deviation from specified camber of flexural members:

$$\pm \frac{1}{32}\text{ inch} \times \frac{\text{No. of ft of total length}}{10}$$

or $\pm \frac{1}{4}$ inch, whichever is greater

Sweep of flexural members:

$$\frac{1}{8}\text{ inch} \times \frac{\text{No. of ft of total length}}{10}$$

Lateral deviation between center line of web and center line of flange plate at contact surface (welded construction):

$\frac{1}{4}$ inch maximum

Deviation from flatness of girder webs in the length between stiffeners or in a length equal to depth of girder:

Intermediate stiffeners on both sides of web:

Web thickness not less than 1/150 of its depth:

1/150 of total web depth

Web thickness less than 1/150 of its depth:

1/120 of total web depth

Intermediate stiffeners on only one side of web:

Web thickness not less than 1/100 of its depth:

1/150 of total web depth

Web thickness less than 1/100 of its depth:

1/100 of total web depth

No intermediate stiffeners:

1/150 of total web depth

Deviation of bottom flange and of bearing plate from a plane normal to plane of web at the bearing, in width of flange .... $\pm \frac{1}{32}$ inch

Combined warpage and tilt of flange of welded flexural members shall be determined by measuring the offset at toe of flange from a line normal to the plane of the web through the intersection of the center line of web with the outside surface of the flange plate. This offset shall not exceed 1/200 of total width of flange or ⅛ inch, whichever is greater.

Out of flatness of seats or bases:

To be set on grout: ⅛ inch maximum

To be set on steel, hard masonry, canvas or lead: 1/100 inch maximum

Deviation from specified depth for welded flexural members, measured at the web center line:

For depth up to 36 inches, incl. .... $\pm \frac{1}{8}$ inch maximum

For depth over 36 inches to 72 inches, incl. .... $\pm \frac{3}{16}$ inch maximum

For depth over 72 inches .... $\pm \frac{5}{16}$ inch maximum

or $- \frac{3}{16}$ inch maximum

2.1.8 Planing Sheared Edges

(a) Sheared edges of plates of main material more than ⅝ inch thick shall be planed to a depth of ¼ inch. Web plates and pin plates (regardless of thickness) of pin connected tension members shall be universal mill plates or shall have edges planed ¼ inch and the ends back of pins planed ¼ inch.

2.1.9 Lacing Bars

(a) The ends of lacing bars shall be rounded unless otherwise required.

2.1.10 Fit of Stiffeners

(a) The ends of stiffeners on flexural members at points of bearing, as defined in Art. 1.7.7, shall be milled or ground to bear against the flange, or shall be welded to the flange with a full groove weld if permitted by Art. 1.10.11.

(b) The fit of intermediate stiffener ends against the flange shall be such as to exclude water after being painted, except that for welded flexural members the ends of stiffeners adjacent to the tension flange may be cut back with one inch clearance.

(c) Fillers and splice plates under angle stiffeners shall be made to fit within ¼ inch at each end.

2.1.11 Flexural Member Web Plates, Riveted and Bolted Construction

(a) The edges of web plates of riveted or bolted flexural members that have no cover plates shall not be more than ⅛ inch above or below the backs of the top flange angles. Web plates of such members with cover plates may be ½ inch less in width than the distance back to back of flange angles.

(b) In riveted or bolted splices of web plates there shall be not more than ⅜ inch opening between the plates.

2.1.12 Facing Floorbeams, Stringers, and Girders

(a) Floorbeams, stringers, and girders having end connection angles shall be made to exact length. If facing is necessary, the thickness of the end connection angles shall not be reduced more than ⅛ inch at any point.

(b) The ends of the web shall be within ⅛ inch of the backs of the end connection angles.

2.1.13 Abutting Joints

(a) In joints and splices of compression members and girder flanges, and of tension members where so specified on the drawings, the abutting surfaces shall be faced and brought to an even bearing. Where the abutting surfaces are not faced, the opening shall not be more than ¼ inch.

2.1.14 Pin Clearances

(a) The difference in diameter between the pin and the pin hole shall be 1/50 inch for pins up to 5 inches in diameter, and 1/32 inch for larger pins.

2.1.15 Pins and Rollers

(a) Pins and rollers shall be turned accurately to gage and shall be straight, smooth, and free from flaws.

2.1.16 Fitting of Base and Cap Plates

(a) Both top and bottom surfaces of base and cap plates of columns and pedestals shall be planed or straightened and the parts of members in contact with them faced to fit. Connection angles for base plates and cap plates shall be connected to compression members before the members are faced.

2.1.17 Surfaces of Bearing Plates and Pedestals

(a) Sole plates of plate girders shall be in full contact with the girder flanges. Sole plates and masonry plates shall be planed or straightened. In cast pedestals, bearing surfaces to be in contact with steel or masonry shall be planed.

(b) The surface finish of bearing and base plates and other bearing surfaces that are to be in contact shall conform to United States of America Standards Institute requirements, as defined in current USASI B 46.1 Surface Roughness, Waviness and Lay, Part I: Sliding Bearings USASI 125.

2.2 RIVETED AND BOLTED CONSTRUCTION

2.2.1 Rivets and Riveting

(a) Rivet dimensions shall conform to the current requirements of the United States of America Standards Institute for large rivets, ½ inch in nominal diameter and larger, USASI Standard B18.4.

(b) Rivets shall be heated uniformly to a light cherry red and driven while hot to fill the holes completely. They shall be free from slag, scale and carbon deposit. Loose, burned, or otherwise defective rivets shall be replaced. In removing rivets, care shall be taken not to injure the adjacent metal and, if necessary, they shall be drilled out. Caulking or recupping shall not be done.

(c) Rivets shall be driven by direct-acting riveters where practicable. The pressure shall be continued after the upsetting has been completed.

(d) If rivets are driven with a pneumatic riveting hammer, a pneumatic bucker shall be used where practicable.

(e) Driven rivet heads shall be full, neatly made, concentric with the rivet holes, and in full contact with the member.

2.2.2 High-Strength Bolts, Nuts and Washers

(a) High-strength bolts, nuts and washers shall conform to the current Specification for Structural Joints Using ASTM A 325 or A 490 Bolts approved by Research Council on Riveted and Bolted Structural Joints, except that other types of fasteners permitted by Art. 2 (d) of that Specification shall not be used.

2.2.3 Installation Procedure for High-Strength Bolts

(a) High-strength bolts shall be installed in accordance with the procedure for the installation of high-strength bolts using the turn-of-nut method of the current Specification for Structural Joints referred to in Art. 2.2.2 (a). All high-strength bolts shall have a hardened washer under the turned element. In addition, a hardened washer shall be used under the non-turned element of A 490 bolts used to connect A 36 material, and may be used under that element for other conditions if so specified by the engineer or elected by the contractor. Beveled hardened washers shall be used where an outer face of the bolted parts has a slope of more than 1:20 with respect to a plane normal to the bolt axis.

2.2.4 Field Fasteners

(a) The number of field rivets furnished in excess of the nominal number required shall be 10 percent plus 10 rivets for each size and length.

(b) The number of field high-strength bolts furnished in excess of the nominal number required shall be 5 percent plus 5 bolts of each size and length. The number of nuts and washers furnished in excess of the nominal number required shall be 5 percent of each size and type.

2.2.5 Size of Holes for Fasteners

(a) The diameter of holes shall be specified in odd sixteenths of an inch, as $\frac{13}{16}$, $\frac{15}{16}$, etc.

(b) The diameter of holes punched full-size and of finished holes reamed or drilled shall be $\frac{1}{16}$ inch greater than the nominal diameter of the rivets or high strength bolts.

(c) The diameter of the punch shall be the diameter of the hole to be punched, and the diameter of the die shall be not more than $\frac{3}{32}$ inch greater.

2.2.6 Preparation of Holes for Shop Fasteners

(a) Holes for shop fasteners shall be subpunched, or subdrilled at the fabricator's option, ¼ inch less in diameter than that of the finished holes, and shall be reamed to size with the parts assembled, with the following exceptions:

(1) Holes in material thicker than ⅞ inch shall not be punched; however, at the fabricator's option, they may be subdrilled to the diameter specified for subpunching or may be drilled full-size with the parts assembled, provided that the parts are adequately bolted or clamped together.

(2) Holes in rolled beams and plate girders, including stiffeners and active fillers at bearing points, may be subpunched ⅛ inch less in diameter than that of the finished holes and reamed to size after assembly, in material not thicker than the nominal diameter of the fastener less ⅛ inch.

(3) Holes in material not more than ⅞ inch thick for fasteners which do not transfer stress caused by vertical live load may be punched full-size, or, at the fabricator's option may be subpunched ⅛ inch less in diameter than the finished holes and reamed to size after assembly. This applies to holes for stitch fasteners, lateral, longitudinal or sway bracing and their connecting material, lacing stay plates, diaphragms which do not transfer shear or other stress, inactive fillers, and stiffeners not at bearing points. However, holes through assembled material shall not pass through both reamed plies and plies punched full-size unless:

The reamed holes have been subpunched for the fabricator's convenience, or

The assembled material is not over five plies thick, of which the main material consists of not more than three plies.

2.2.7 Preparation of Holes for Field Fasteners

(a) Holes for field fasteners shall be subpunched or subdrilled at the fabricator's option, ¼ inch less in diameter than that of the finished holes, and shall be reamed to size through steel templates with hardened steel bushings, with the following exceptions:

(1) Field splices in plate girders and in the chords of trusses shall be reamed with the members assembled. Other field connections may be reamed with the members assembled, at the fabricator's option. Chord splices of truss members shall, in all cases, be reamed or drilled with at least three abutting sections assembled and with milled ends of compression chords in full bearing.

(2) Assemblies, such as floor systems to girders, complete trusses, rolled beam spans connected by diaphragms, and portals to trusses shall be reamed with the members assembled if so indicated on the contract plans, and otherwise at the fabricator's option.

(3) Field connections of lateral, longitudinal or sway bracing shall conform to the requirements of holes for shop fasteners.

(4) Holes in material thicker than ⅞ inch shall not be punched but shall be subdrilled to the diameter specified for subpunching, or drilled full-size with parts assembled.

2.2.8 Reaming and Drilling After Assembly

(a) Reaming, or drilling full-size, of assembled parts or assembled members shall be done after the parts or members are so firmly bolted or clamped together that the surfaces are in close contact. Parts shall be separated before final joining if necessary for removal of any shavings.

2.2.9 Match-marking

(a) Connecting parts assembled in the shop for the purpose of reaming or drilling holes in field connections shall be so match-marked that they may be reassembled in the same position. The parts shall not be interchanged. Diagrams showing such match-marks shall be furnished to the engineer.

2.2.10 Templates for Reaming and Drilling

(a) All steel templates shall have hardened steel bushings in holes accurately dimensioned from the center lines of the connection as inscribed on the template. The center lines shall be used in locating accurately the template from the milled or scribed ends of the members.

2.2.11 Reaming and Drilling Through Templates

(a) Reaming, or drilling full-size of field connections through templates shall be done after the templates have been located with the utmost care as to position and angle, and firmly bolted. Templates used for the reaming of matching members, or of the opposite faces of one member, shall be exact duplicates. Templates for connections which duplicate shall be so accurately located that like members are duplicates and require no match-marking.

(b) When templates are used to ream field connections of web members of a truss at least one end of each web member shall be milled or scribed normal to the long axis of the member and the templates shall be accurately set at both ends from this milled or scribed end. Templates for reaming gussets of a truss shall be accurately set and located to the true geometric dimensions shown on the shop plans before reaming or drilling.

(c) Templates for field holes for joining shop-connected floor sections to girders or trusses shall be of such dimensions and so applied as to space the field holes correctly from one floor expansion point to the next.

2.2.12 Fitting for Shop Riveting or Bolting

(a) The parts of riveted or bolted members shall be adequately pinned, firmly drawn together in close contact, with bolts before riveting or final bolting is begun. Tack welding shall not be used. The drifting done during assembly shall be only such as to bring the parts into position and not to enlarge the holes or distort the metal.

2.2.13 Finished Holes

(a) Holes shall be cylindrical, unless punched full-size, and perpedicular to the member. They shall be clean-cut without torn or ragged edges. Burrs on the outer surfaces shall be removed. Where the grip exceeds 4½ inches the holes shall be filleted $\frac{1}{32}$ inch.

2.2.14 Offset in Finished Holes

(a) The offset in any hole reamed ¼ inch in any ply of material measured from an outer ply after the hole has been finished for riveting or bolting, shall not exceed $\frac{1}{16}$ inch. Not more than 10 percent of the holes shall provide as much offset as $\frac{1}{16}$ inch, and not more than 20 percent shall provide as much offset as $\frac{1}{32}$ inch.

(b) The offset in any ply reamed $\frac{1}{8}$ inch or punched full-size in any ply of material measured from an outer ply after the hole has been finished for riveting or bolting, shall not exceed $\frac{1}{8}$ inch. Not more than 10 percent of the holes shall provide as much offset as $\frac{1}{8}$ inch, and not more than 20 percent shall provide as much offset as $\frac{1}{16}$ inch.

(c) If approved by the engineer, holes may be overreamed to meet these requirements, and larger rivets or bolts installed.

2.3 WELDED CONSTRUCTION

2.3.1 General

(a) These specifications cover requirements for welding practices and inspection to ensure that the resulting structure will be satisfactory for service. The current Specifications for Welded Highway and Railway Bridges of the American Welding Society (AWS D2.0) shall be used for all requirements not specifically covered in these specifications and for all detail welding procedures.

2.3.2 Preparation of Material for Welding

(a) Surfaces and edges to be welded shall be smooth, uniform and free from fins, tears, cracks and other defects which would adversely affect the quality or strength of the weld. Surfaces to be welded shall also be free from loose scale, slag, loose rust, grease, moisture or other material which will prevent proper welding. Mill scale which withstands vigorous wire brushing, a light film of drying oil or a thin rust-inhibitive coating may remain, except that all mill scale shall be removed from the surfaces on which flange-to-web welds for flexural members are to be made. Surfaces within 2 inches of any weld location shall be free from any paint or other material which would prevent proper welding or produce objectionable fumes while welding.

2.3.3 Assembly of Material for Welding and Control of Distortion and Shrinkage

(a) In assembling and joining parts of a structure or of built-up members, and in welding reinforcing parts to members, the procedure and sequence shall be such as will minimize distortion and shrinkage. Before the start of welding on a member or structure in which shrinkage stresses or distortion is likely to affect the adequacy of the structure, the program for welding sequence and distortion control shall be approved by the engineer.

(b) All shop splices in each component part of a cover-plated beam or built-up member shall be made before such component part is welded to other component parts of the member. If approved by the engineer, long girders or girder sections may be made by shop splicing sub-sections each of which has been fabricated as specified in this paragraph.

(c) In making welds under conditions of severe external shrinkage restraint, the welding shall be carried continuously to completion or to a point that will insure freedom from cracking before the joint is allowed to cool below the minimum specified preheat and interpass temperature.

(d) The parts to be joined by fillet welds shall be brought into as close contact as practicable, and in no event shall be separated by more than $\frac{3}{16}$ inch. If the separation is $\frac{1}{16}$ inch or greater, the leg of the fillet weld shall be increased by the amount of the separation. The separation between faying surfaces of lap joints and of butt joints landing on a backing shall not exceed $\frac{1}{16}$ inch. Where irregularities in the steel, after straightening, do not permit contact within the above limits, the procedure necessary to bring the material within these limits shall be subject to the approval of the engineer.

(e) Abutting parts to be joined by butt welds shall be carefully aligned. Where the parts are effectively restrained against bending due to eccentricity in alignment, an offset not exceeding 10 percent of the thickness of the thinner part joined, but in no case more than $\frac{1}{8}$ inch may be permitted as a departure from the theoretical alignment. In correcting misalignment in such cases, the parts shall not be drawn into a greater slope than $\frac{1}{2}$ inch in 12 inches. Measurement of offset shall be based upon center line of parts unless otherwise shown on the drawing.

(f) Dimensions of the cross section of groove-welded joints which vary from those shown on the detail drawings by more than the following workmanship tolerances shall be referred to the engineer for approval or correction:

Root face of joint	$\pm \frac{1}{16}$ inch
Root opening of joints without steel backing	$\pm \frac{1}{16}$ inch
Root opening of joints with steel backing	$+ \frac{1}{8}$ inch, $- \frac{1}{16}$ inch
Groove angle of joint	$\pm 5°$

2.3.4 Flange-to-Web Welds of Flexural Members

(a) Flange-to-web welds of flexural members shall be made by the automatic submerged arc process, or by the automatic gas metal-arc process.

2.3.5 Tack Welds and Temporary Welds

(a) Transverse tack welds on tension flanges of flexural members are prohibited.

(b) Tack welds shall be subject to the same quality requirements as the final welds except that:

(1) Preheat is not mandatory for single pass welds which are remelted and incorporated into welds made by the submerged arc or gas metal-arc process.

(2) Defects such as undercut, unfilled craters and porosity need not be removed before final welds when final welds are made by the submerged arc or gas metal-arc process.

(c) Tack welds which are not incorporated into the final weld shall be removed. Tack welds which are incorporated into the final weld shall be cleaned thoroughly. Multiple pass tack welds shall have cascaded ends.

(d) Temporary welds shall be subject to the same welding procedure requirements as the final welds. They shall be removed unless otherwise permitted by the engineer. When they are removed, the surface shall be made flush with the original surface.

2.3.6 Backings, Extension Bars and Run-Off Plates

(a) Backings, extension bars and run-off plates used for groove welds shall be of ASTM A 36 steel, or of steel of at least equal strength and weldability. Backings shall be removed from all members carrying live load stress, and from other members where the backings are exposed. Backings shall be removed by a procedure which shall not injure the base metal or the weld metal, and the weld metal surface

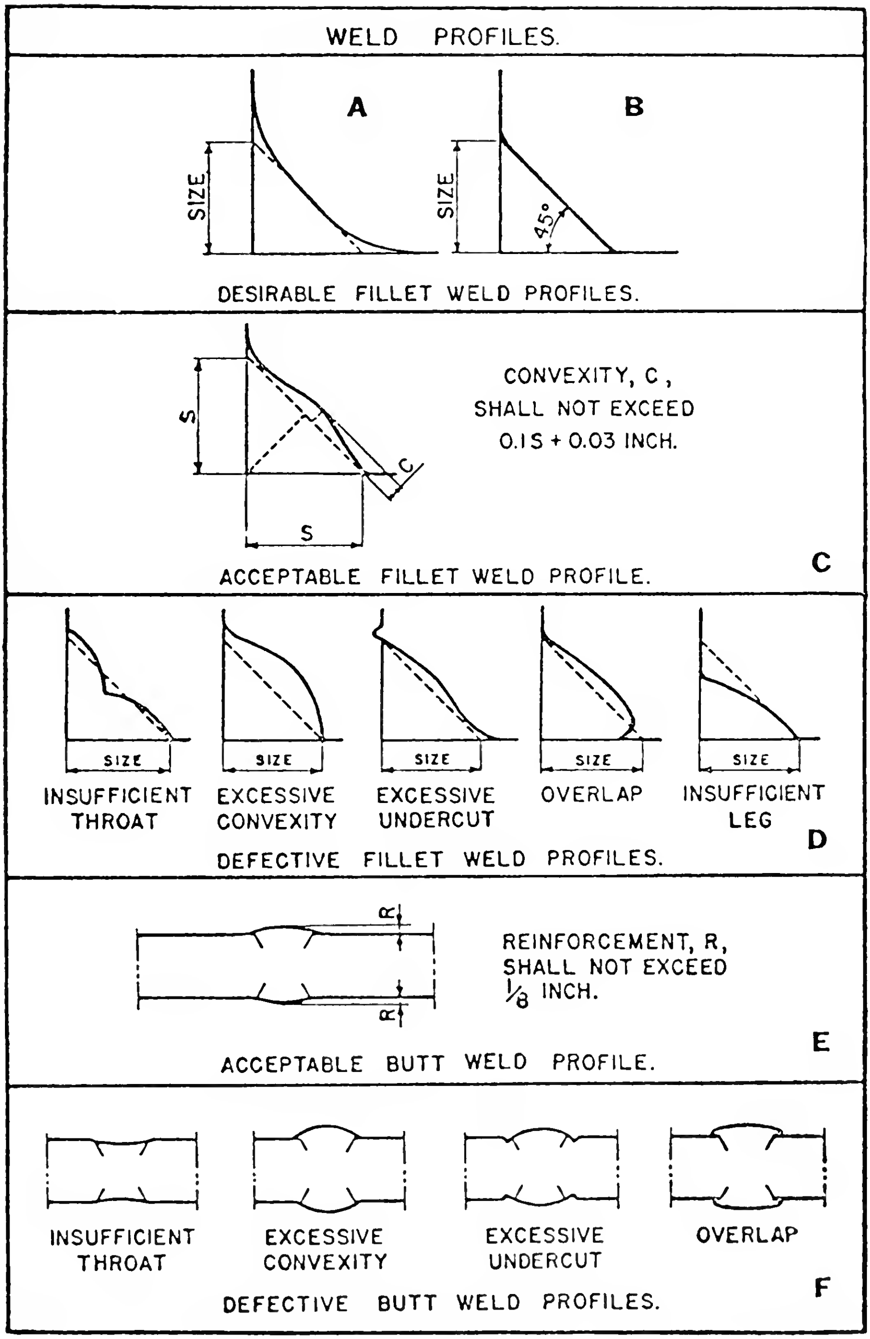

Fig. 3—Weld profiles.

shall be left flush or slightly convex with the full throat thickness. Extension bars and run-off plates shall be removed upon completion of the weld and the ends of the weld made smooth and flush with the abutting parts.

2.3.7 Details of Welds

(a) All fillet welds shall be of desirable or acceptable types as shown in Fig. 3 A, B and C, with no defects such as those shown in Fig. 3D. In no case, except at the outside of a corner joint, shall the convexity exceed the value 0.1 S + 0.03 inch, where S is the actual size of the fillet weld in inches. (See Fig. 3C.)

(b) Butt welds shall preferably be made with a slight or minimum reinforcement, except as may be otherwise provided, and shall have no defects such as those shown in Fig. 3F. The height of reinforcement shall not exceed ⅛ inch. (See Fig. 3E.)

2.3.8 Quality of Welds

(a) There shall be thorough fusion between weld metal and base metal and between successive passes in the weld. All craters shall be filled to the full cross section of the weld.

(b) The sum of diameters of piping porosity[1] shall not exceed ⅛ inches in any linear inch of weld and shall not exceed ¾ inches in any 12 inch length of weld.

(c) Welds shall have no cracks and, regardless of the method of inspection, shall have no other defects exceeding the following limits in size or frequency of occurrence:

(1) The greatest dimension of any porosity[2] or fusion-type defect[3] that is $\frac{1}{16}$ inch or larger in greatest dimension shall not exceed the size, Dimension of Defect, B, indicated in Fig. 4 for the joint or weld throat thickness involved. The distance from any porosity or fusion-type defect described above to another such defect, to an edge or to the toe of a flange-to-web fillet weld shall not be less than the Minimum Clearance Allowed, C, indicated by Fig. 4 for the size of defect under examination. The limitations given by Fig. 4 for 1½ inch joint or weld throat thickness shall apply to all joints or weld throats of greater thickness.

(2) Independent of the requirements of Art. 2.3.8 (c) (1), the sum of the greatest dimensions of porosity and fusion-type defects less than $\frac{1}{16}$ inch greatest dimension shall not exceed ⅜ inch in any linear inch of weld.

(3) Undercut shall not be more than 0.01 inch deep when its direction is transverse to the primary stress in the part that is undercut. Undercut shall not be more than $\frac{1}{32}$ inch deep when its direction is parallel to the primary stress in the part that is undercut.

(4) Welds shall be free from overlap.

2.3.9 Corrections

(a) In lieu of rejection of an entire piece or member containing welding which is unsatisfactory or which indicates inferior workmanship, the corrective measures listed hereunder may be permitted by the engineer, whose specific approval shall be obtained for making each correction.

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[1] Piping porosity signifies pinholes that are elongated generally in a direction normal to the face of the weld and extend to the surface of the weld.

[2] Porosity signifies gas pockets and any similar generally globular type voids.

[3] Fusion-type defect signifies slag inclusions, incomplete fusion, inadequate penetration and similar generally elongated defects in weld fusion.

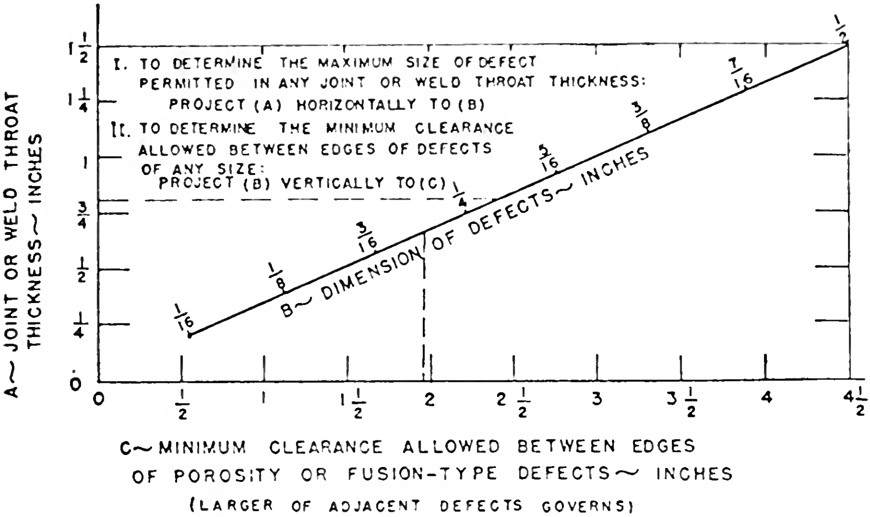

Fig. 4—Weld quality requirements (limitations of porosity and fusion-type defects).

(b) Defective or unsound welds or base metal shall be corrected either by removing and replacing the entire weld, or as follows:

(1) Excessive convexity, overlap: reduce by removal of excess weld metal.

(2) Excessive concavity of weld or crater, undersize welds, undercutting: clean and deposit additional weld metal.

(3) Excessive weld porosity, slag inclusions, incomplete fusion: remove defective portions and reweld.

(4) Cracks in weld or base metal: remove weld throughout its length, unless the extent of the crack can be ascertained by the use of acid etching, magnetic particle inspection or other equally positive means, in which case sound weld metal 2 inches beyond each end of the crack shall be removed, followed by the required rewelding.

(c) The removal of weld metal or portions of the base metal shall be done by chipping, grinding, oxygen cutting, oxygen gouging, or air carbon-arc gouging and in such a manner that the remaining weld metal or base metal is not nicked or undercut. Defective portions of the weld shall be removed without substantial removal of the base metal.

(d) Additional weld metal shall be deposited using an electrode preferably smaller than that used for making the original weld, and preferably not more than $\frac{5}{32}$ inch diameter. The surfaces shall be cleaned thoroughly before welding.

(e) Where work performed subsequent to the making of a deficient weld has rendered the weld inaccessible or has caused new conditions which would make the correction of the deficiency dangerous or ineffectual, the original conditions shall be restored by removing welds or members or both before making the corrections, or else the deficiency shall be compensated for by additional work done according to an approved revised design.

(f) Caulking of welds shall not be permitted.

(g) Improperly fitted parts may be cut apart and rewelded. Members distorted by welding shall be straightened by mechanical means or by carefully supervised application of a limited amount of localized heat. The temperature of heated areas shall not exceed 1200° F (a dull red color). Parts to be heated for straightening shall be substantially free of stress and from external forces, except those stresses resulting from mechanical means used in conjunction with the application of heat.

2.3.10 Peening

(a) No peening shall be done on the root or surface layers of a weld. Peening of intermediate weld layers may be used only if authorized by the engineer and directed by him. Care shall be exercised to prevent overpeening which may cause overlapping, scaling, cracking, flaking or excessive cold working of weld and base metal.

2.3.11 Stress-Relief Heat Treatment

(a) Where required by the contract plans or specifications, welded assemblies shall be stress relieved by heat treating. Finish machining shall be done subsequent to heat treatment. The weld assembly shall be adequately supported in the furnace. The temperature shall be maintained uniformly throughout the furnace during heating and cooling so that no two points on the assembly will differ by more than 100° F at any time. Accurate pyrometer equipment shall be provided and installed with the thermocouple junctions located at the hottest and coolest points on the assembly, but not in the direct path of the heating flames. After a mean temperature range between 1100° F and 1200° F is reached, the temperature of the assembly shall be held within that range for one hour per inch of thickness of the thickest part. When the assembly has cooled to 600° F it may be removed from the furnace unless cooling to a lower temperature is required to prevent distortion.

2.3.12 Welder and Welding Operator Qualifications

(a) Welds shall be made only by welders, welding operators and tack welders who have been previously qualified by tests as prescribed in the current Specifications for Welded Highway and Railway Bridges of the American Welding Society (AWS D2.0) to perform the type of work required. Certification by the fabricator for each welder, welding operator and tack welder involved that he has been thus qualified within 12 months previous, and that he has been doing satisfactory work of the required type within the three months previous period shall be considered sufficient evidence of the qualification of each welder, welding operator or tack welder involved in the work.

2.3.13 Welds and Welding Procedure Qualification

(a) Welds and welding procedures which are to be employed under these specifications shall be previously qualified by tests as prescribed in the current Specifications for Welded Highway and Railway Bridges (AWS D2.0) of the American Welding Society. The engineer, at his discretion, may accept evidence of previous qualification of welds or welding procedures presented by the fabricator.

2.4 SHOP PAINTING

2.4.1 Shop Painting of Structural Steel

(a) Steel surfaces, except as noted below, shall be prepared and painted in accordance with the recommendations of the Steel Structures Painting Council Manual, Vol. 2. The surface preparation and painting shall be in accordance with the particular system selected and specified by the engineer from Table I—General Painting Guide for Steel Structures, of the Manual.

(b) For welded construction, slag shall be cleaned from all welds. Welded joints shall not be painted until after the work has been completed and accepted. The surfaces to be painted shall be cleaned of spatter, rust, loose scale, oil and dirt. Weld surfaces that have not been blast cleaned shall be neutralized by suitable methods before painting.

(c) Shop and field contact surfaces shall not be painted.

2.4.2 Shop Painting of Machined Surfaces

(a) Machine finished surfaces of steel (except abutting joints and base plates) shall be protected against corrosion by a rust-inhibiting coating which can readily be removed prior to erection, or which has characteristics which make removal unnecessary prior to erection. This coating shall be applied as soon as the surfaces have been finished and approved by the inspector.

(b) Abutting joints and base plates shall be painted as required by Art. 2.4.1 (a).

2.5 INSPECTION

2.5.1 Facilities for Inspection

(a) The contractor shall afford the inspector, without charge, facilities for the inspection of materials and workmanship. The inspector shall be allowed free access to the parts of the works used in the fabrication.

2.5.2 Inspector's Authority

(a) The inspector shall have authority to reject materials or workmanship that do not meet the requirements of these specifications. In case of dispute, the contractor may appeal to the engineer, whose decision shall be final.

2.5.3 Rejection

(a) The acceptance by the inspector of material or finished members shall not prevent their rejection later if found defective.

(b) Rejected material and workmanship shall be replaced promptly or made good by the contractor.

2.5.4 Inspection—High-Strength Bolted Joints

(a) The inspector shall observe the installation and tightening of bolts to determine that the specified tightening procedure is properly used, and shall determine that all bolts have been tightened. He shall verify the attainment of the specified tension by use of an "inspecting wrench" as described in the current Specifications for Structural Joints Using A 325 or A 490 Bolts approved by the Research Council on Riveted and Bolted Structural Joints as frequently as necessary to insure consistency in the bolt installation procedure.

2.5.5 Inspection—Welded Work

(a) All weld inspection shall be performed by the inspector, or shall be witnessed by him. The fabricator shall place pieces so that the inspector has ready access. When specified on the design plans or in special provisions covering the work, the fabricator may be required to perform specific non-destructive testing work, such as radiography, etc., but this must be witnessed by the inspector. The inspector must not unnecessarily delay such inspection by refusing to be present when this work must be done.

(b) All fillet welds shall receive a complete and careful visual inspection to insure that their size, length and location conform to Art. 2.3.7 (a) and to the detail drawings, and that they meet the quality requirements of Art. 2.3.8. Magnetic particle inspection of fillet welds in accordance with ASTM E 109, Tentative Method for Dry Powder Magnetic Particle Inspection, may be required by the engineer by specific statement on design plans or in special provisions covering the work.

(c) All groove welds carrying live-load stress in flanges of flexural members and in tension members shall be inspected by radiographic, ultrasonic or other non-destructive testing method which will satisfactorily present evidence to the engineer that the welds meet the quality requirements of Art. 2.3.8. At least 10 percent of other groove welds shall be similarly inspected. For each such groove weld which does not meet the requirements of Art. 2.3.8, two additional welds shall be similarly inspected.

(d) The procedures to be followed for radiographic or ultrasonic testing of welds shall be those specified in the current Specifications for Welded Highway and Railway Bridges (AWS D2.0) of the American Welding Society.

2.6 SHIPMENT AND PAY WEIGHT

2.6.1 Marking and Shipping

(a) Erection marks shall be painted on the members. The weight shall be marked on members weighing more than 10 tons.

(b) Rivets and bolts shall be in separate packages according to length and diameter. Loose nuts and washers shall be in separate packages according to size. Pins, other small parts, and packages of rivets, bolts, nuts, and washers shall be shipped in boxes, crates, kegs, or barrels, none of which exceeds 300 lb gross weight. On the outside of each container shall be marked plainly a list and description of the material therein.

2.6.2 Loading Long Girders

(a) Long girders shall be so loaded and marked that they may be delivered at the bridge site in position for erection without turning. Instructions for such delivery shall be given to the receiving carrier.

2.6.3 Shipment of Anchorage Material

(a) Anchor bolts, washers, and other anchorage or grillage materials to be built into the masonry shall be shipped in time therefor.

2.6.4 Pay Weight

(a) The payment in pound-price contracts shall be based on the weight of the metal in the fabricated structure. This pay weight shall be computed in accordance with Section 3 of the Code of Standard Practice of the American Institute of Steel Construction.

Report on Assignment 3

Protection of Steel Surfaces

M. L. Koehler (chairman, subcommittee), D. S. Bechly, E. T. Bond, E. T. Franzen, E. F. Garland, G. W. Haffey, W. C. Howe, E. A. Johnson, T. J. Mearscheimer, J. Payne, A. L. Piepmeier, W. F. Robey, R. D. Spellman.

Your committee submits the following report as information:

A field application has been made to evaluate various protective systems, other than paint, under actual exposure conditions where brine is present. Four systems are included:

1. Covering the steel with an asbestos-bonded, galvanized sheet metal.
2. Metallizing with a hot zinc spray.
3. Applying a cathodic layer of zinc powder in an epoxy resin base.
4. Applying a proprietary cathodic coating with a top coat sealer.

Two locations were selected: The Seaboard Coast Line's Altamaha River bridge near Everett, Ga. and the Huey Long bridge in New Orleans, La. The SCL bridge consists of two 138-ft truss spans with 38-ft beam span approaches. It has an open deck. On the truss spans, the surfaces involved are the floorbeam web plates between the stringer connection angles and the trusses, and the top surfaces and edges of the top and bottom stringer flanges. On the beam spans, the surfaces coated were the same as the stringers. The Huey Long bridge application was to 7-in. by 10-in. plates bolted to the bridge deck.

The 16-gage asbestos-bonded, galvanized plates were bolted to the floorbeam webs and the edges were sealed by caulking.

The hot zinc metallizing was done by railroad forces with their equipment. All surfaces were sandblasted prior to spraying.

The zinc-rich epoxy resin coating was applied by brush in two coats, 24 hours apart. All surfaces were sandblasted.

The proprietary cathodic coating consisted of two coats plus a seal coat. Application was by brush to sandblasted surfaces.

The application to the SCL bridge was made during October 1966. The Huey Long bridge plates were coated at the same time and shipped to New Orleans.

An inspection of the SCL application was made on November 16, 1967, by a member of the AAR research staff. All four systems appeared to be in good condition and adequately protecting the steel surfaces. Some ties had shifted slightly, but the coatings were not abraded. There was some rust staining on the top flanges of the beam spans, and at the next inspection it would be desirable to move a few ties to inspect the bearing surfaces. Also, on the top flanges of the stringers, the zinc-rich coating was flaking off in a few spots, but it was observed that sand was under the coating. Apparently not all of the blasting sand was removed before the coating was laid down. The floorbeam webs and all the bottom flanges show no evidence of coating breakdown.

Report on Assignment 7

Bibliography and Technical Explanation of Various Requirements in AREA Specifications Relating to Iron and Steel Structures

J. G. Clark (chairman, subcommittee), T. J. Boyle, J. L. Durkee, J. M. Hayes, J. J. Fiala, G. F. Fox, A. Hedefine, D. V. Messman, G. T. Nagtegaal, M. Schifalacqua, J. D. Tapp, R. H. Wengenroth, W. Wilbur.

Your committee submits the following report as information:

Your committee is working on the complete revision of Chapter 15 of the Manual. The work under Assignment 7 is being closely coordinated with this revision so that the resulting changes will be adequately covered when revised Chapter 15 is ready for publication.

Innovations in Bridge Construction and Maintenance*

By E. T. FRANZEN

Chief Engineer, Missouri Pacific Railroad

When I finished school in the depression in the '30s, it seemed important to get a degree and then get a job. But I still had an interest in learning so I took night-school courses of interest to me. All were in engineering, except one was a philosophy class where we had to write a paper stating our observation of life. My basic observation was that all things must change. This may sound simple but take a look about you—and at yourself—and see the resistance to change. The problem, of course, is to channel the change in the right direction—and consider that defining of "right" has caused endless friction and wars. Change and innovation are almost synonymous but change can be in any direction whereas innovation implies a right direction.

After accepting this assignment, I was surprised to see how often the word innovate appears today, and I am sure that this is a measure of a great effort to change. But in searching for topics to report to you today, I was disappointed in how few I could find that would be significant and of general interest to you. What I will report on are personal observations in contrast to the consensus reports of your committees.

Although we don't have many washouts on the Missouri Pacific that require bridging, our operating vice president was heard to remark at one of them that he would once in his lifetime like to work on a railroad that did not have any bridges. Under the circumstances, I can understand his comment. To get rid of bridges completely would be the ultimate in bridge innovation. As we cannot eliminate bridges, we must consider areas where we can improve our bridge structures and make them more economical.

As a young draftsman in a railroad bridge department, I was quite impressed with my ability to convert academic terms such as moment of inertia, radius of gyration, and section modulus into plans that soon became bridges. Bridge draftsmen on this railroad also had to serve part of the time as a member of a bridge inspection team. After looking at bridges for a few years, I came to realize that there was more to the art of designing bridges than applying text book formulas, as the bridge must also fit a given location. As my responsibilities increased, I found that there was a third factor—cost—which was really the most significant factor. The purpose of these preliminary remarks is to point out that innovations must meet certain criteria. Adherence to text book theory and a good specification will assure that a structure is strong enough. Field inspections will generate experience that will assure that the structure is practical. A study of costs will guide us towards economy in design. But if your innovation does not meet each of these three criteria of strength, usefulness and economy, you can be sure that you are only dreaming. There is a fourth criteria—appearance—that is generally ignored on railroads as railroad bridges rarely, if ever, win prizes for grace or beauty. We need not, however, make apologies for the appearance of railroad bridges, so long as they are simple and uncluttered. Architectural embellishments do not improve the appearance, in my opinion, and only add to the cost.

* Paper presented by Mr. Franzen (then engineer of structures of the Missouri Pacific) at the Third Regional Meeting of the American Railway Engineering Association, Dallas, Tex., November 7, 1967.

I will review some of the things that I have considered innovations. You must keep in mind, however, that what may appear to me as an innovation may already be standard practice on another railroad.

Bridges can be readily classified as timber, steel, or concrete even though there is some intermingling. Timber bridges in this part of the country constitute the major volume of bridging and, therefore, should give the greatest opportunity for innovations. Actually, there has been little change in the basic form of the timber bridge for many years. In revising our timber bridge standards recently, I noted that there had been no changes in some of the plans for a period of 41 years. The simplicity of construction of the timber trestle has made it resistant to innovation and resulted in highly similar structures on all railroads. I had opportunity to redesign the standards for timber bridges for a railroad and after some thought, established a criteria for redesign that each piece of timber in the bridge was to be examined and the smallest size used that would be compatible with function. Even with a pioneering spirit, I found that I could develop little change in the timber trestle. In examining the ballasted-deck timber trestle, we found that the number of stringers could be reduced from eleven to nine 8x16's on a 14-ft panel and still carry the specified E 60 live load. This reduction in the number of stringers also permitted reducing the width of the bridge from 14 to 12 ft. It took a while to get accustomed to the narrower width and there was some opposition, but what real argument is there against a 12-ft-wide ballasted deck when the same railroad was using ties 9 ft long on its open-deck timber trestle. We also experimented with the deck for ballasted-deck bridges on curves. The practice had been to use a level deck and raise the ballast stop on the outside of the curve to accommodate the superelevation in the track. On sharp curves, this required very high ballast curbs on the outside of the curve. We built a few bridges with the superelevation in the cap the same as is done on the open-deck bridge, which permitted the use of the same ballasted deck on curves as was used on tangent. There was opposition to this change as the feeling was that the ballast would roll down the inclined deck plank to the low side of the curve. Observation of these bridges showed that there was no difference in performance between them and the flat deck.

If you wish to experiment, the following can be considered. Although I have seen most of them tried, I do not take credit for originating them:

(1) If you really want to save money, why not use a square-sawed track tie on open-deck bridges at about half the cost of a timber bridge tie.

(2) Why not use caps 12 ft long instead of the customary 14 ft, or better yet, why not use prestressed concrete as some railroads are doing.

(3) Why not use concrete backwalls in place of timber to reduce maintenance costs of timbers that are highly vulnerable to decay. The Missouri Pacific has used the concrete backwalls for many years and found them to be economical and maintenance free.

(4) What is the optimum treatment for timber—straight creosote or a combination of creosote and coal tar?

This would be a good place to talk about trainmen's walks on bridges which seem to offer bridge people great opportunity to innovate. The railroad for which I first worked had developed 29 different types of railing posts, which would indicate a real spirit of innovation, but they were actually making only minor changes in a firmly entrenched standard. The Missouri Pacific has reduced its walk and railing down to what I feel is a minimum. We now use a steel angle post 2½ x 2½ in at about 14 ft centers to support two lines of ½ in galvanized strand. This is a considerable reduction from the old standard which used 3½ x 3½ in angles and two lines of 2-in pipe. The AREA recommends use of a 4 x 4-in steel angle. I suspect that if we really searched our conscience, we could use only one line of wire rope, but the savings would be negligible and likely not comparable to loss in safety. About a year ago, our Mechanical Department advised us that running boards from freight cars would become surplus and that a large volume of this light steel grating would become available for our use. Our first impression was that the grating was too light to serve as a walkway, but we have now found that we can make a very respectable walk out of this grating that would otherwise be scrapped. Incidentally, we are also using this grating for catwalks for piggyback facilities.

The construction and maintenance of timber bridges appears to be as resistant to innovation as the design. The difficulty with construction or repair of timber bridges is that the pieces are too small, must be handled one at a time and are secured with a multitude of fastenings. Our crews do panel decks and preassemble stringer chords but there is no way to escape driving one pile at a time, placing one brace at a time, or one cap at a time. Power tools and equipment have been developed to make more economical the maintenance and construction of timber bridges and of these, small cranes capable of operating on rail or on highway are probably the most effective labor-saving devices.

Steel bridges are presently in a state of evolution and until recently all railroad bridges were assembled with rivets or pins. The railroads have been slow to accept welding for assembly of steel structures, with the possible exception of the Pennsylvania Railroad. The Pennsylvania Railroad has used welding for many years and other roads are now coming to recognize its economy. Except in special cases, our railroad will use shop welding for fabrication of bridges. The economy of welding as compared to riveting was clearly demonstrated in purchase of two through plate-girder spans, 62 ft long, two years ago. Plans were made for both riveted and welded girder spans and proposals obtained for both types. The riveted spans were estimated to weigh 84 tons for which a low bid of $32,832 was submitted for an average cost of 19.5 cents per pound. The welded spans were estimated to weigh 74 tons for which a low bid of $26,496 was submitted for an average cost of 18 cents per lb. The welded spans saved 10 tons of metal and were purchased at a cost of $6,435 less than comparable riveted spans. There is a natural squeamishness on the part of bridge engineers to accept full butt welds in tension members as occurs in the bottom flanges of girders. We found that consideration could be given to use of a single full-length bar for the bottom flange, as the amount of metal saved in stepping the bottom flange for spans under 70 ft was offset by the cost of making the butt welds.

Along with the gradual acceptance of welding has come a very rapid acceptance of the high-strength-steel bolt as a replacement for rivets. Extensive tests that have been carried on by the Research Council on Riveted and Bolted Structural Joints have clearly shown that the high-strength bolt is a better fastener than the rivet. Its cost is about double that of a rivet of the same length and size, but this increased material cost can be readily overcome by lower erection costs. Practically all of our field connections for bridges are made now with high-strength bolts. We will experiment with the use of the Huck bolt fastener for bridge work early next year to determine its economy. The Huck bolt is a patented device similar to the high-strength bolt but uses a special collar that is swaged onto the corrugated shank of the bolt by use of a hydraulic tool. Our Mechanical Department uses many Huck bolts in fabricating cars.

Chapter 15 of the AREA Manual covering Iron and Steel Structures has been, since its inception, a riveted work specification. Your Committee 15 has about finished a complete revision of its Manual material that will make the new chapter a riveted, welded and bolted specification all on an equal basis. Prior to this, reference to bolting was relegated to the appendix and reference to welding was to the specification of the American Welding Society. This major revision of Chapter 15 should speed the acceptance of welding and bolting of railroad structures.

The railroads are frequently accused of being laggard or conservative in acceptance of new ideas. In writing the new Chapter 15, the railroads will be in the forefront in the use of high-strength bolts. Present bolt specifications require use of a lower allowable unit stress when joints are subjected to stress reversal, severe stress fluctuations or where slippage would be undesirable. Under this limitation, designers tend to be conservative and used the lower allowable unit stress for all joints, which largely eliminated the economy of high-strength bolts. The new AREA specifications will provide a single allowable stress for high-strength bolts that will permit, under all circumstances, the use of two A 325 bolts in place of three rivets or the use of one A 490 super-high-strength bolt for two rivets.

Not painting steel structures may not seem like an innovation. Some railroads have been forced into this innovation by not having money to do all things that custom indicated is needed. These railroads found that steel did not melt away through corrosion if it were not painted. I sometimes suspect that paint salesmen have done an excellent job of brainwashing people. After observing bridges that had not been painted in 40 or 50 years, without any appreciable loss of metal, I came to the conclusion that painting of steel structures is not necessarily required. I can recall seeing one bridge on which the only discernible paint were the erection marks and a paint date. The paint date showed that the structure had not been painted in 40 years, yet the span was in perfect condition with much of the mill scale still showing. It is interesting to see in the last few years that the major steel companies are now actively progressing not painting of special grades of steel. I wonder if the claims for the special grades of steel would not also apply to A 36 steel equally as well. Missouri Pacific's present policy is to grease-coat main line bridges below a level of 4 ft above the rail; the grease is applied generally to those structures where there is a likelihood of active corrosion from brine drip from refrigerator cars. We also have a corrosion problem on lines near the Gulf as a result of winds carrying salt inland. In these areas, we are using an asphalt coating that will dry to a non-slippery surface for use on truss spans where grease would be objectionable as a safety hazard for inspectors. I still love aluminum paint because of its appearance, because it makes a bridge easy to inspect and can be easily climbed on. But those of us who are responsible for maintenance cost must take a look at the cheaper substitutess, as our experience shows that they are effective in protecting the steel where corrosion is a problem. Extensive tests have shown, however, that the steel must be relatively clean before the coating is applied.

Floating steel spans into place is not an innovation but floating one from East Central Arkansas to Houston, Tex., likely sets a new distance record for floating a major span. A spur track that we are building out of Baytown, Tex. required, by ruling of the Corps of Engineers, a high-level crossing or movable span. The high-level crossing was not economical and, fortunately, we had available in a line recently abandoned west of Memphis a 162-ft lift span. We had talked about floating the truss span out of the old bridge as one of several possible methods of moving the bridge, and after entering into an agreement with a contractor, this method was elected by him. The procedure was quite straightforward. Contrary to our usual feelings, we had to pray for heavy rains and reasonable high water in the St. Francis River in Arkansas last spring to permit floating out the span. The weather finally cooperated and the span is now resting on new piers over Cedar Bayou near Baytown, 830 miles from home. We don't claim the automatic operation of this span as our invention as the automation is patterned after a similar operation in use by the Frisco. The span will be left normally in the raised position and the lowering operation initiated by an approaching train activating track signal circuits. There will be an electric eye under the bridge to prevent lowering the span onto a boat.

Missouri Pacific's concrete trestle practice was described in a recent issue of *Track and Structures* so that I will now point out only a few areas where we are experimenting. About a year ago, we purchased a power auger that can drill holes in the ground up to 48 in. in diameter. This auger was originally purchased to drill holes to guide the piling for construction of a bridge on an offset line where we did not have the benefit of an existing bridge in which to build templates. This auger paid for itself on this one job in Arkansas where we built 3,162 ft of bridge for a new section of double-track railroad. We have experimented with this auger to drill shafts for a two-legged bent where rock or shale was comparatively near the surface. We plan to increase the use of drilled shafts as it appears to me that we should be able to drill two holes in the ground and fill them with concrete purchased locally cheaper than we can cast three piling in Little Rock, and load them, ship them hundreds of miles, unload them, build templates, hammer piling into the ground, and then cut them off.

It is our policy to use ready-mix concrete for field use but occasionally ready-mix concrete cannot be conveniently brought in. For these places, we have designed a precast cap that is cast at Little Rock and can be fastened to the tops of three driven piling with dowels and an epoxy grout. We built one bridge this summer using these precast caps and it was successful enough for the bridge and building supervisor to want us to redesign our abutments so that we can use precast caps for them and a steel sheet-pile backwall. The current design of our standard concrete trestles is something of an innovation in that we use standard reinforced beams whereas other railroads use prestressed beams. Our costs have been carefully analyzed by us and by our Industrial Engineering Department and show conclusively that we can produce conventionally reinforced beams for lower cost than we can buy prestressed concrete beams. In my opinion, the cost of the concrete trestle is its most interesting feature. *Track and Structures* reported that an analysis of cost for 25 bridges showed an average cost of \$150.48 per ft. In writing the article for *Track and Structures*, we did not elaborate on the cost analysis, but I can assure you that we did not select 25 low-cost bridges to obtain the average, but used Accounting Department figures for the first 25 bridges that had been completed to the new design standard. You may be interested to know that this average includes one bridge at Trinity, Tex. that cost \$237.00 per ft because of severe train interference, conversion of an existing ballasted-deck timber bridge, and a heavy grade raise. Two other bridges were built south of Longview, Tex., at an average cost of \$212.00 per ft and had high costs for the same reasons. To offset these high costs, the average included a bridge built at Eunice, La., 610 ft long, where we had optimum conditions such as no train interference, an existing open-deck bridge, and no grade raise. This bridge was built for an average cost of $115.75 per ft. The average also includes a bridge, 191 ft long, north of Houston, Tex., that was built for $126.00 per ft. We believe that we can build the concrete trestle for the same cost as a timber trestle and get a better bridge.

I am sure that I have scanned too rapidly the subject of innovation in bridge work but time does not permit a detailed review of each subject. I continually urge people I am associated with to generate new ideas, as without ideas, we will never progress. I urge them also to look at the wealth of new materials and new equipment, as these, too, are opening up new possibilities for improving our bridges. I am sure that with good judgment and a little courage that we can develop innovations that will produce better bridges at a lower cost and, perhaps equally important, reduce interference to train operation so that our vice presidents may come to like bridges.

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February 1968

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The reports in this issue of the Bulletin will be presented to the 1968 Annual Convention of the Association at the Palmer House, Chicago, March 19–21, 1968. Comments and discussion with respect to any of the reports are solicited, and should be addressed to the chairman of the committee involved, in writing, in advance of the Meeting, or from the floor during the Meeting.

* The contents of this Bulletin and the other Bulletins of the Association from Bulletin 608, September–October 1967, to and including Bulletin 614, June–July 1968 (except Bulletin 613, March 1968), will constitute the Annual Proceedings of the Association, Vol. 69.

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Those whose names are shown in boldface in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 1.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Brief progress statement, submitted as information .... page 513

2. Physical properties of earth materials:
   (a) Roadbed. Load capacity. Relation to ballast. Allowable pressures.
   Study is in progress looking to revising Manual material on this subject into a more complete and useful form, but no report is presented at this time.

   (b) Structural foundation beds, collaborating as necessary or desirable with Committees 6 and 8.
   Study is in progress looking to revising Manual on this subject material into a more complete and useful form, but no report is presented at this time.

3. Natural waterways: prevention of erosion.
   Study is in progress to update Manual material, but no report is presented at this time.

4. Drainage and culverts.
   (a) Use of tunnel liner plate in connection with culvert and casing pipe installations, collaborating as necessary or desirable with Committee 15.
   Study is in progress, but no report.
   (b) New types of drainage pipes.
   Progress report, submitted as information .... page 513

5. Specifications for pipelines for conveying flammable and non-flammable substances, collaborating as necessary or desirable with Committees 15 and 20.
   Progress report, submitted as information .... page 514

6. Roadway: formation and protection.
   (a) Roadbed stabilization.
   Report on lime-soil stabilization investigation for railroad roadbed, submitted as information .... page 516
   (b) Special treatments for subgrade improvement.
   No report.
   (c) Hydraulic fills, collaborating as necessary or desirable with Committee 25.
   No report.

7. Tunnels.
   (a) Ventilation.
   No report.
   (b) Methods used to increase clearance, collaborating as necessary or desirable with Committee 28.
   Study in progress, but no report.
   (c) Methods of open cutting.
   Study is in progress, but no report.

8. Fences.
   No report.

9. Roadway signs.
   (a) Reflectorized and luminous roadway signs, collaborating as necessary or desirable with Committees 5 and 9, and with the Communication and Signal Section, AAR.
   No report.

10. Ballast.
   (a) Tests.
   Progress report on ballast research project, submitted as information .... page 527
   (b) Special types of ballast.
   No report.

11. Control of vegetation, collaborating as necessary or desirable with Communication and Signal Section, AAR.
Progress report, submitted as information .... page 529

THE COMMITTEE ON ROADWAY AND BALLAST,
C. E. WEBB, *Chairman.*

AREA Bulletin 612, February 1968.

Report on Assignment 1

Revision of Manual

L. J. DENO (chairman, subcommittee), R. D. BALDWIN, M. W. COX, W. M. DOWDY, E. E. FARRIS, G. F. NIGH, S. J. OWENS, F. L. PECKOVER, E. L. ROBINSON, JR., N. E. WHITNEY, JR., D. H. YAZELL.

Chapter 1 of the Manual was reviewed during the year and no changes other than editorial are recommended.

Report on Assignment 4

Drainage and Culverts

W. M. DOWDY (chairman, subcommittee), C. W. BEAN, T. F. DECAPITEAU, J. F. FAYCOSH, G. C. FENTON, H. E. MOORE, W. M. SNOW.

(b) NEW TYPES OF DRAINAGE PIPES

Your committee presents the following report as information. It covers types of drainage pipe other than metal, concrete and clay. The types of drainage pipes discussed herein may be generally classed under the heading of plastic or fibre pipe.

Plastic pipe is not a new product; it has a history of some 35 years and a hoped-for sales volume of $350 million in 1972. There are a dozen or more kinds of plastic pipe on the market today; however, the polyethylene, ABS (styrene, acrylonitrile, butadeine) and PVC (polyvinyl chloride) pipes make up the greater percentage of present pipe production.

This report considers only the use of the smaller sizes of plastic pipe for subsurface drainage (diameters of 3 in, 4 in, 5 in and 6 in) in comparing such pipe with other types of subdrainage pipe.

Both non-perforated and perforated plastic pipes in the smaller diameters and with crush strengths from 600 to 1000 psi are on the market today for use in subsurface drainage. Perforated plastic pipes are available with single and double rows of perforations with hole diameters ranging from 5/16 to 5/8 in on 3 to 5-in centers and from 90 to 160 deg apart.

Some of the advantages claimed by the plastic pipe industry are: (1) long, lightweight lengths, (2) easy handling, (3) no waste, (4) excellent hydraulic characteristics, (5) flexibility and toughness, (6) non-corrodible, (7) economy, (8) resistance to shock and vibration.

At the present time the cost of plastic pipe compares favorably in the smaller diameters with metal pipe, with the cost of plastic pipe on a downward trend as demand increases.

Some of the disadvantages are reported to be: (1) lack of resistance to high temperatures, (2) brittleness, (3) weathering, (4) high thermal expansion, (5) susceptibility to creep, (6) non-electrical grounding usefulness. In addition, small changes in compounding or fabricating the materials going into the pipe can materially affect its performance.

Know your supplier and seek expert advice when considering any large scale use of plastic pipe.

As of this date we have had no report from any railroad as having used plastic pipe for subsurface drainage purposes.

It is the opinion of this committee that a control specification is not warranted at this time.

Report on Assignment 5

Specifications for Pipelines for Conveying Flammable and Non-Flammable Substances

Collaborating with Committees 15 and 20

E. E. Farris (chairman, subcommittee), C. W. Bean, R. H. Beeder, C. R. Bergman, T. F. DeCapiteau, G. B. Harris, B. G. Hudson, H. L. VanHorn, M. E. Vosseller, A. J. Wegmann.

Your committee submits the following report as information.

1. Study is continuing on how to present pipeline specification and installation procedure material in a non-technical manner for the benefit of supervisory personnel or inspectors.

2. Tests of simulated 8, 12 and 24-in uncased pipeline crossings have been completed by the research staff of the Association of American Railroads, and the results have been turned over to the Battelle Memorial Institute for analysis and correlation of data.

3. Action has been initiated through the AAR to protect railroad interests in current legislation entitled "The Natural Gas Pipeline Safety Act of 1967", as well as during development of standards prescribed for oil pipelines by legislation in 1965. The following objectives have been established.

(a) Receive a copy of all proceedings and material presented in connection with preparation of standards for oil pipelines under the 1965 legislation.
(b) Receive information concerning status of the natural gas legislation and schedule of hearings.
(c) Secure a copy of all proceedings and material presented in connection with formulation of standards proposed by current legislation.
(d) The proposed regulations (oil and gas) should not nullify the right of AREA to continue to formulate, revise, and clarify its existing recommendations deemed necessary to establish pipeline safety.

4. The following material concerning the use of a drilling fluid in boring for pipeline undercrossings of track is presented in response to inquiry, and for information only. It is an extract from standards used by one state highway department:

"If the applicant elects to bore with a drilling fluid, . . . the use of either a gel-forming colloidal drilling fluid or the use of a polymer-surfactant mixture in accordance with the following specifications is permitted.

"The drilling fluid is used to lubricate the cutters or reamers, as a binder to bind the cuttings into plugs of appropriate length and to form a filter cake around the circumference of the bore in order to prevent cave-ins or spalling, to maintain the arch and also to lubricate the bore for easy removal of masses or plugs of cuttings from the bore by using compressed air. Liquids other than the drilling fluids described in Alternates 1 and 2 will not be used in the bore. The intemperate use of drilling fluid causing undue flow back and erosion of the bore or the violation of any specification as set out in the permit will be cause for cancelling the permit. All bores accomplished with the use of a drilling fluid will be made as follows:

"ALTERNATE 1. The casing or carrier pipe is to be installed by drilling a hole of a size not larger than 1" around the outside circumference of the casing or carrier pipe where same is larger than 8" in diameter and not larger than ½" around the outside circumference where same is 8" or less in diameter, with an open-type bit that leaves the cuttings in place. A gel-forming colloidal drilling fluid consisting of at least 10% by weight of Aqua-jel, or the equivalent of other gel-forming types, when boring in sandy subsoils, fine sands, water bearing sands or any soils which easily spall or cave, and consisting of at least 5% by weight of Aqua-jel or the equivalent of other gel-forming types when boring in dense consolidated soils will be used to consolidate the cuttings, seal the wall of the bore and furnish lubrication for subsequent removal of the cuttings and installation of the casing immediately thereafter. The percentage of gel-forming agent will be increased as required by soil conditions. All information necessary to establish the quality or equivalency of other gel-forming types will be furnished by the applicant. When boring sandy soils, fine sands, water bearing sands or any soil which easily spalls or caves, the bore entrance will be plugged or dammed in order to retain the drilling fluid and the cuttings within the bore until immediately before the casing or carrier pipe is installed. Water bearing sands and mucky soils will be well pointed as necessary prior to commencing the bore. When drilling through dense consolidated soils the cuttings may be partially removed from the hole in approximately 3-ft plugs by use of compressed air, or by retraction of the cutter or reamer. No cutter or reamer larger than 3" in diameter shall have holes therein larger than 5/16" in diameter through which drilling fluid is forced during boring.

"ALTERNATE 2. The casing or carrier pipe is to be installed by drilling a hole of a size not larger than 1" around the outside circumference of the casing or carrier pipe with an open-type bit that leaves the cuttings in place. Drilling fluid composed of water and a polymer-surfactant of approximately 61% diesel fuel, 15% sodium carboxy methyl cellulose of same quality as Drisbac, 21.5% water and 2.5% anionic surfactant will be used to consolidate the cuttings, seal the wall of the bore and furnish lubrication for subsequent removal of the cuttings and installation of the casing or carrier pipe immediately thereafter. When boring sandy subsoils, fine sands, water bearing sands, or any soil which easily spalls or caves, the bore entrance will be plugged or dammed in order to retain the drilling fluid and the cuttings within the bore until immediately before the casing or the carrier pipe is installed. Water bearing sands and mucky soils will be well pointed as necessary prior to commencing the bore. When drilling through dense consolidated soils the cuttings may be partially removed from the hole in approximately 3-ft plugs by use of compressed air. The polymer-surfactant mixture or drilling fluid when used in dense consolidated soils will consist of not less than 2% of polymer-surfactant by volume and when used in sandy subsoils, fine sands or any soil which easily caves will consist of at least 4% of polymer-surfactant by volume. The percentage of polymer-surfactant will be increased as required by soil conditions. All information necessary to establish the quality or equivalency of any ingredient will be furnished by the applicant."

The use of such additives would seem to protect pipe coatings during installation and form a tight seal to the pipe, but there is a question as to the desirability of introducing any fluid or lubricant into the roadbed, or materials which might contribute to the corrosion problem. It might be well to require the outer 3 ft of the casing to be backfilled with soil and tamped.

Report on Assignment 6

Roadway: Formation and Protection

(a) Roadbed Stabilization

(b) Special Treatments for Subgrade Improvement

G. F. Nigh (chairman, subcommittee), H. E. Bartlett, D. L. Bloem, S. F. Burmeister, I. P. Cook, H. K. Eggleston, J. F. Faycosh, E. M. Hardin, H. O. Ireland, E. C. Jordan, A. E. Lewis, W. G. Murphy, J. E. Newby, S. R. Pettit, W. J. Sponseller.

Editorial changes in Part 1 of Chapter 1 of the Manual as recommended by the committee were published in the Manual Recommendation Supplement to Bulletin 610, December 1967.

Your committee presents the following report as information. It is entitled "Lime Soil Stabilization Investigation for Railroad Roadbed," and was prepared under Assignment (a).

Lime-Soil Stabilization Investigation for Railroad Construction

INTRODUCTION

The stabilization of soils with lime has been employed for many years in highway and airport construction and more recently and to a lesser extent on railroads. Increased volume and weight of traffic on highways as well as airports have over the years resulted in increased requirements in pavement design. Stable, durable road bases are vital to good roads. There is no particular problem in areas where satisfactory base course materials are economically available in quantity. However, in areas where this is not the case it becomes necessary to solve the problem through the modification or improvement of marginal base course materials by the use of additives such as lime. Several railroads have successfully employed lime-stabilized soils as substitutes for conventional granular sub-ballast materials in recent years in areas where suitable sub-ballast materials are not available.

Lime is an effective stabilizer when added to most fine-grained clay soils. Lime added to clayey soils will generally produce two beneficial modifications. First, a decrease in the plasticity index of the soil will occur, and second, a long-term cementing action will take place as a result of chemical reactions between the lime and silica and alumina in the soil. In addition there are other notable advantages of adding lime to soils. Hydrated lime has the ability to dry out a soil which is overly wet and sticky due to heavy rains or poor drainage—often enough to permit compaction equipment to proceed under otherwise impossible conditions. The lime, in addition to changing the character of clayey soils, will absorb a considerable amount of moisture. Lime will increase the ease of manipulation of soils, breaking up clay clods so that a more thorough mix is obtained with less effort. Unlike cement, lime sets slowly over a much longer period of time and there is no critical time factor for completing compaction. During construction, this slow-setting characteristic of lime provides more flexibility. This characteristic could be a detriment, however, if lime stabilization is used in the fall of the year in areas where early freezing temperatures and long, cold winters may cause serious damage. Under these conditions, the lime-stabilized section may never fully set or develop its potential strength and the full advantage of the lime would not be realized.

There are two major soil types where the addition of lime will probably not be of benefit. These are (1) soils with high organic content which, because they require large amounts of lime to satisfy the reactions would make the cost prohibitive, and (2) fine-grained silty soils, which are relatively non-plastic and are not improved to any great extent by the addition of lime.

Scope and Materials

Laboratory tests were conducted in the AAR Engineering Research Laboratory on three soils from the vicinity of Baytown, Tex., supplied by a Gulf-area railroad. The railroad was shortly to start construction on a new industrial lead. The only sub-ballast economically available in the area is mud sheel from the Gulf and this was getting relatively scarce and expensive. The purpose of the laboratory tests was to determine the feasibility of stabilizing the available soils with hydrated lime so that they might be used as sub-ballast on the lead.

The soils used in the test will be referred to as Soil No. 1, Soil No. 2 and Soil No. 3. Soil No. 1 is classified as a clay loam, Soil No. 2 is a silt loam and Soil No. 3 is a clay. A sample of the lime which the railroad proposed to use was furnished and was used in the laboratory tests.

LABORATORY TEST PROCEDURES

Preparation of Materials

The soils were air-dried, disaggregated with as little manipulation as possible and passed through a No. 10 screen. It will be noted that 100 percent of all three soils passed the No. 10 screen. The soils were then placed in individual air-tight containers so that a uniform moisture content could be maintained.

Grain Size Analysis

A representative 500-g sample of each of the air dry soils was obtained and oven dried to a constant weight. The oven-dry sample was then thoroughly mixed and reduced by use of a sample splitter to a 50-g sample. The 50-g sample was placed in a 16-oz bottle and covered with a 4 percent solution of sodium hexametaphosphate (a dispersing agent) and allowed to stand for 1 hr. The clay fraction was removed by elutriation and the remaining portion was oven-dried and sieved. A grain size distribution curve was drawn up for each soil.

Lime-Soil Mixtures—pH Test

Lime is a strong base which, in water, gives a pH of 12.40. The reaction of lime and soil is a series of chemical reactions which are basically the reaction of calcium with organic and inorganic compounds making up the soil. A rapid method that gives the amount of lime consumed in a lime-soil mixture has been developed. The pH of the various lime-soil slurries is obtained after 1 hr to determine the percent of lime that has reacted with a soil. The lowest amount of lime to give a pH of 12.40 is the amount necessary for stabilization of that soil. Additional amounts of lime may, however, give greater long-term strength due to chemical reactions which produce long-term cementing action. This quick test to determine lime requirements for lime stabilization was developed by James L. Eades, research assistant professor, and Ralph E. Grim, research professor, Department of Geology, University of Illinois.

Moisture-Density Relationships

Moisture-density tests were run on the untreated soils as well as on the various lime-soil mixtures. The Harvard miniature compaction apparatus was used. These tests determine the relationship between the moisture content of the various lime-soil mixtures and resulting densities. The results of these tests were used in molding strength test specimens and will also be useful as a guide for control of compaction in the field during construction.

Unconfined Compression Test

The pH test determines the lime required for stabilization, but a strength test is necessary to show the percentage of strength increase. Specimens for the unconfined compression tests were molded using the Harvard miniature compaction apparatus. Lime-soil mixtures were proportioned by weight and mixed dry. Sufficient water was added to bring the moisture content of the mixtures up to optimum. Two specimens were molded for each untreated soil and for each lime-soil mixture. The molded specimens were extruded from the mold, wrapped in damp paper towels and placed in air-tight containers in which they were cured for 72 hrs at 140 F. Life-soil specimens moist cured in the laboratory for 72 hrs at 140 F will closely approach 1 year field strength. Upon completion of curing, the specimens were tested to failure in an unconfined compression testing machine. Strain was applied at the rate of 0.05 in per min.

Atterberg Limit Tests

Liquid limit and plastic limit tests were run on the untreated soils and the various lime-soil mixtures. The liquid limit is the moisture content of a soil at which it changes from a plastic state to a liquid state. The plastic limit is the moisture content of a soil at which it changes from a plastic state to a solid state. If the

TABLE 1
TEST RESULTS FOR SOIL NO. 1

Textural Composition

Percent Sand	30.7
Percent Silt	46.5
Percent Clay	22.8

Classification

Clay Loam

Atterberg Limits

	Raw Soil	3% Lime	5% Lime	7% Lime
Liquid Limit	26.6			
Plastic Limit	20.8			
Plasticity Index	5.8	Non Plastic	Non Plastic	Non Plastic

Moisture-Density Tests

	Raw Soil	3% Lime	5% Lime	7% Lime
Max. Density	111.2 psi	108.0	106.7	106.2
Optimum M.C.	14.7%	15.1	16.0	16.4

pH Test

Mixture	pH
2% Lime	12.1
3%	12.2
4%	12.3
5%	12.4
6%	12.4

Unconfined Compression Tests (72 hr. Moist. Cure at 140° F.)

Mixture	Unconf. Comp. Str.-psi (Avg. of 2 Test Specimens)
Raw Soil	22 psi
3% Lime	222
5% Lime	307
7% Lime	286

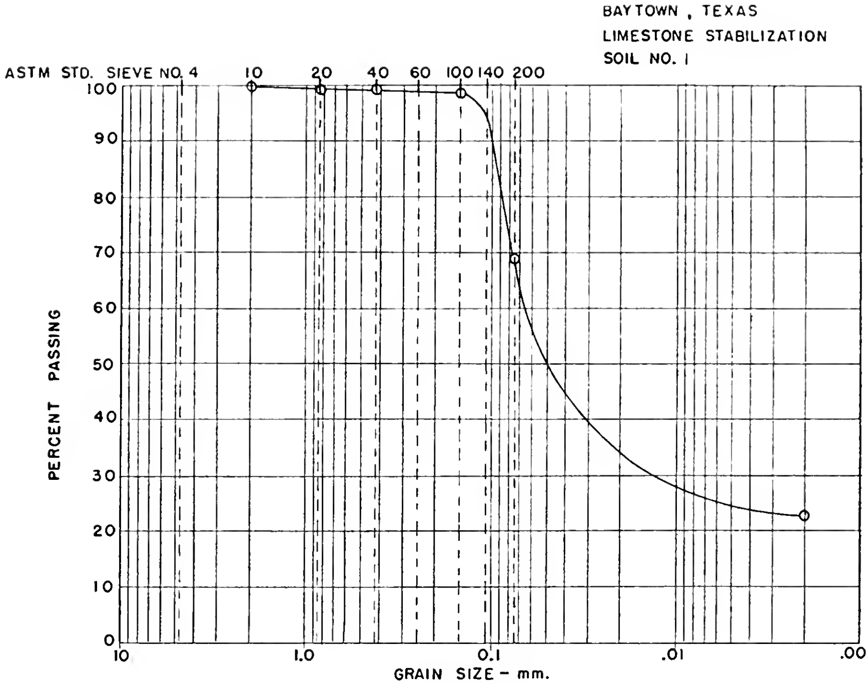

FIGURE 1 GRAIN SIZE CURVE

plastic limit is subtracted from the liquid limit it gives the plasticity index (P.I.) which is the range of moisture contents over which a soil remains in a plastic condition and is a measure of the plasticity of a soil. A lowering of the P.I. indicates a reduction in plastic properties of a soil. The samples for the liquid limit and plastic limit tests were taken from the unconfined compression test specimens after they had been cured and tested.

TEST RESULTS

Soil No. 1

Test results for Soil No. 1 are shown in Table 1. This soil has 30.7 percent fine sand, 46.5 percent silt, and 22.8 percent clay-size particles and is classified as a clay loam. The grain size distribution curve is plotted in Fig. 1. The pH test results indicate that this soil will require 5 percent lime for stabilization. The moisture density tests, results of which are plotted in Fig. 2, show a typical decrease in maximum density and increase in optimum moisture content as the percent of lime is increased. Samples were molded of the untreated soil and with 3, 5, and 7 percent lime added. These samples, as previously noted, were moist-cured at 140 F for 72 hrs and then subjected to the unconfined compression test. There was a substantial increase in unconfined compressive strength with the addition of 3 percent lime and an additional increase for 5 percent with a slight fall off in strength

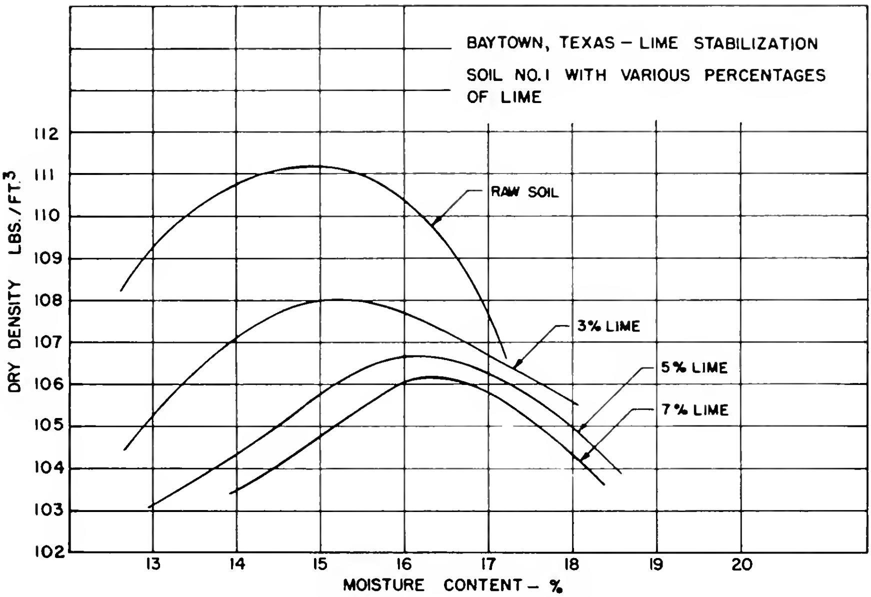

FIGURE 2 MOISTURE - DENSITY TEST

at 7 percent lime. The untreated soil has a relatively low plasticity (Plasticity Index—8.8). The soil is reduced to a non plastic condition with the addition of 3 percent lime and remains non plastic for subsequent lime additions.

Soil No. 2

Test results for Soil No. 2 are shown in Table 2. This soil has 14.7 percent sand, 72.1 percent silt, and 13.2 percent clay-size particles and is classified as a silt loam. The grain-size distribution curve is plotted in Fig. 3. The results of the moisture-density tests are plotted in Fig. 4. It will be noted that the maximum density increases with no appreciable change in optimum moisture content with the addition of 4 percent lime. The addition of 6 percent and 8 percent lime decreases the maximum density below that for the 4 percent lime sample with no notable change in optimum moisture content. However, the maximum density for the 6-percent and 8-percent lime additions still remains higher than the maximum density for the untreated soil. This soil has a predominance of silt-size particles and probably a relatively high void ratio. When the lime is added to the soil it apparently fills the voids resulting in the higher maximum density. The pH test results indicate that 5 percent of lime is necessary for stabilization. The soil is non plastic and remains so with addition of lime. Results of the unconfined compression tests on cured specimens show that this soil apparently does not yield effectively to lime stabilization. The increase in strength from the untreated state to the lime-treated condition up through the addition of 8 percent lime is negligible.

TABLE 2
TEST RESULTS FOR SOIL NO. 2

Textural Composition

Percent Sand	14.7
Percent Silt	72.1
Percent Clay	13.2

Classification

Silt Loam

Atterberg Limits

Raw Soil - Non Plastic

Moisture - Density Tests

	Raw Soil	4% Lime	6% Lime	8% Lime
Max. Density	106.2 psi	110.6	110.3	108.6
Optimum M.C.	12.3%	11.3	12.2	12.6

pH Test

Mixture	pH
2% Lime	12.2
3%	12.2
4%	12.3
5%	12.4
6%	12.4
7%	12.4

Unconfined Compression Tests (72 hr. Moist. Cure at 140° F.)

Mixture	Unconf. Comp. Str.-psi (Avg. of 2 Test Specimens)
Raw Soil	12.0 psi
4% Lime	18.5
6% Lime	24.5
8% Lime	25.5

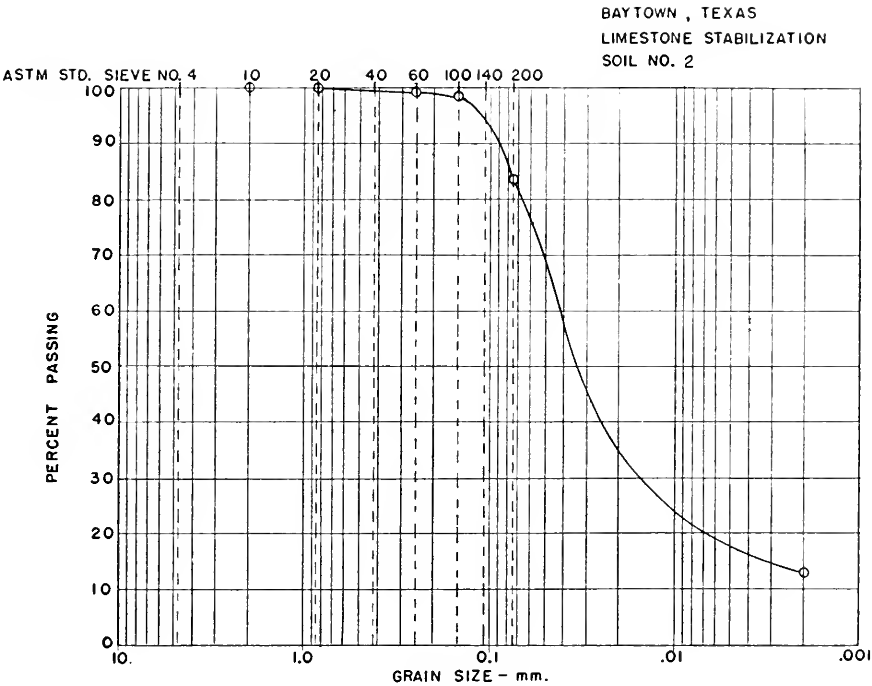

FIGURE 3 GRAIN SIZE CURVE

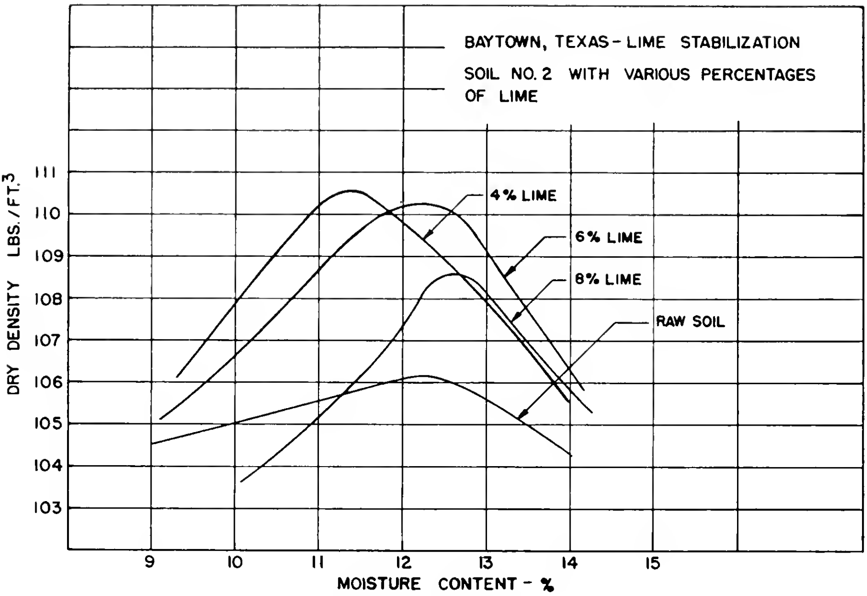

FIGURE 4 MOISTURE-DENSITY TEST

Soil No. 3

Test results for Soil No. 3 are shown in Table 3. This soil is composed of 11.1 percent sand, 38.6 percent silt, and 50.3 percent clay-size particles and is classified as a clay. The grain-size distribution curve is shown in Fig. 5. The pH tests indicate that 3 percent lime is required to stabilize the soil. The moisture-density tests show a decrease in maximum density and an increase in optimum moisture content for the first and each subsequent addition of lime (Fig. 6). The unconfined compressive strength of the untreated soil was 20 psi. The additions of 1 and 2 percent lime produced small increases in the strength. The addition of 4 percent lime produced a substantial increase in unconfined compressive strength to 255 psi. Subsequent additions of lime above 4 percent caused the unconfined compressive strength to fall off slightly from the 4 percent strength. The untreated soil has a liquid limit of 51.0 and a plastic limit of 20.9, giving a plasticity index of 30.1. The addition of 1 percent lime decreases the Plasticity Index to 13.9, 2 percent lime to 10.5 and the addition of 4 percent lime renders the soil non plastic.

CONCLUSIONS AND RECOMMENDATIONS

Soil No. 1 can apparently be effectively stabilized with lime. The pH test indicates that 5 percent lime is necessary to stabilize this soil. An additional 1 percent of lime is generally recommended to insure that there is a sufficient amount of free lime present to accommodate long-term cementing action by the formation of calcium silicates and calcium aluminates. The unconfined compression tests indicate that 6 percent lime will give sufficient strength to support loads transmitted from the track through the ballast section.

TABLE 3
TEST RESULTS FOR SOIL NO. 3

Textural Composition

Percent Sand	11.1
Percent Silt	38.6
Percent Clay	50.3

Classification

Clay

Atterberg Limits

	Raw Soil	1% Lime	2% Lime	4% Lime
Liquid Limit	51.0	36.8	38.3	
Plastic Limit	20.9	22.9	27.8	
Plasticity Indes	30.1	13.9	10.5	Non Plastic

Moisture Density Tests

	Raw Soil	1% Lime	2% Lime	4% Lime
Max. Density	107.7 psi	104.6	101.8	100.2
Optimum M.C.	17.1%	19.0	19.7	20.3

pH Test

Mixture	pH
1% Lime	11.7
2%	12.25
3%	12.4
4%	12.4
5%	12.4

Unconfined Compression Tests (72 hr. Moist. Cure at 140° F.)

Mixture	Unconf. Comp. Str.-psi (Avg. of 2 Test Specimens)
Raw Soil	20 psi
1% Lime	37.5
2% Lime	64
3% Lime	181
4% Lime	255
5% Lime	232

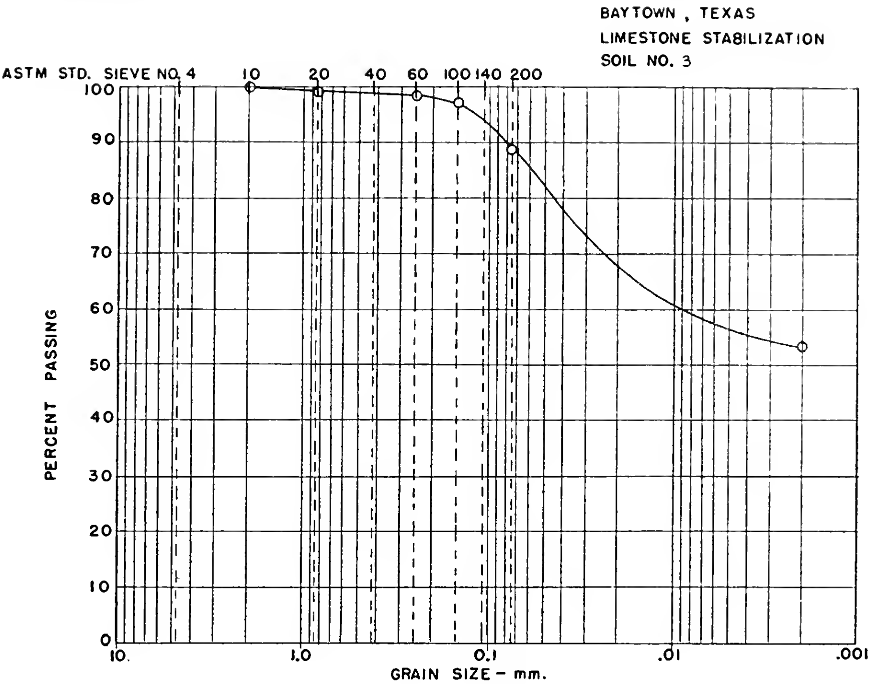

FIGURE 5 GRAIN SIZE CURVE

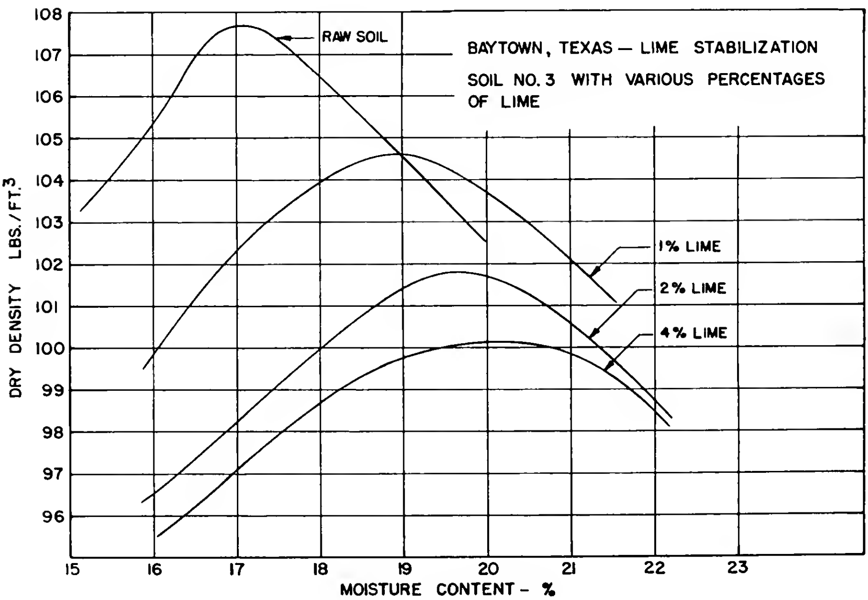

FIGURE 6 MOISTURE-DENSITY TEST

Soil No. 2 apparently does not react favorably to lime stabilization. The pH test shows that reaction takes place between certain compounds in the soil and the lime. However, the unconfined compression tests on the lime-soil mixtures indicate little or no improvement in strength increase. This is primarily a silty soil, and lime is generally not as effective with silty soils as with clays because these soils do not produce as much pozzolanic activity (cementing action by chemical changes) with lime as clayey soils.

Soil No. 3 will produce good results when mixed with lime. The pH test indicates that 3 percent lime is necessary to stabilize this soil. It is recommended to use 4 percent lime, however, because it will allow sufficient lime to give additional strength through long-term cementing action. The unconfined compressive strength tests indicate satisfactory strength at 4 percent lime.

In summary, Soil No. 1 and Soil No. 3 can be satisfactorily stabilized by the addition of lime. It is recommended that 6 percent of lime be used with Soil No. 1 and 4 percent with Soil No. 3. If a sufficient quantity of Soil No. 3 is available it would be advisable to use it exclusively because of the obvious economy involved. Soil No. 2 does not yield to stabilization with lime and is consequently ruled out as a suitable material for this purpose.

Report on Assignment 10

Ballast

E. L. Robinson (chairman, subcommittee), R. H. Beeder, D. L. Bloem, H. K. Eggleston, G. E. Ellis, W. D. Lovell, W. C. McCormick, F. P. Nichols, R. H. Peterson, N. B. Roberts, E. L. Woods.

PROGRESS REPORT ON BALLAST RESEARCH PROJECT

Your committee submits the following report of progress in the gathering of information preparatory to ballast specification development.

Synopsis

The Ballast Specification Development Investigation, reinstated in the Association of American Railroads Engineering Research Budget, was continued in 1967. The first phase of the investigation, the selection and sampling of appropriate materials for the tests, was actively pursued and laboratory tests were run on these test samples. The work is being performed by the research staff of the AAR with the cooperation and assistance of the staff of the National Crushed Stone Association and the National Slag Association. The project is under the general direction of G. M. Magee, director of engineering research, under the guidance of Rockwell Smith, research engineer roadway and is being supervised and reported by G. L. Hinueber, engineering laboratory manager of the AAR.

Materials

Ballast samples have been obtained from nine different track sources where the ballast has been in service for at least five years, and companion samples of unused ballast, which it was hoped would be representative of the track samples, were obtained from the source. In subcommittee discussions it was brought out that the gradation and/or quality at the source of supply can change over a period of years, and that this present method of obtaining comparative samples may not be entirely representative. It was proposed, however, that the investigation should continue along the same lines and that test results be analyzed with these limitations in mind. It was further agreed that an extended method of research and sampling which could provide more reliable results also be carried out. This recommended method would prove for sampling new ballast at the track site as ballast sections are being replaced and storing the samples in the laboratory for five years. A used sample would be secured from the track at the same location after five years of service in track. Comparative laboratory tests can then be conducted on identical used and unused samples to provide information concerning changes in properties of the various ballast materials.

Tests

Laboratory tests are in progress or have been completed on all of the test samples of ballast so far obtained. Each sample is subjected to the following tests: (1) gradation, (2) specific gravity and absorption, (3) sodium and magnesium sulfate soundness tests, (4) water-alcohol freezing and thawing test, (5) Los Angeles abrasion test, (6) Washington degradation test, (7) California Durability Index, (8) modified sound equivalent on both minus No. 10 and minus No. 200 portions, and (9) Atterberg limits on fines from original samples as well as fines produced in Los Angeles abrasion tests.

Since several of these tests are non-standard it might be well to define their purpose at this point.

The water-alcohol freezing and thawing test is a form of soundness test somewhat analogous to the sulfate tests, but one which in many instances can be more predictive.

The Washington degradation test is intended to give a measure of the susceptibility of an aggregate to degrade in service to plastic fines.

The California Durability Index Test is a test procedure which is also designed to predict the relative resistance of an aggregate to produce detrimental clay-like fines.

The California Sand Equivalent Test is a measure of the detrimental clay-like material present in the material tested.

The purpose of these laboratory tests is to evaluate the various test procedures as to their ability to predict the probable field performance of ballast materials.

In addition to the aforementioned laboratory tests, a small-scale repeated-loading test is being devised which it is hoped will give information on break-down and stability of ballast materials under simulated in-track conditions.

Test Results

It is not deemed advisable to give any laboratory test results at this time. Relatively few materials have been tested thus far and the results at best would be inconclusive and possibly misleading.

Report on Assignment 11

Control of Vegetation

Collaborating with Communication and Signal Section, AAR

D. H. YAZELL (chairman, subcommittee), H. C. ARCHDEACON, C. W. BAILEY, F. N. BEIGHLEY, R. H. BOGLE, R. J. BRUCE, S. F. BURMEISTER, T. J. HERNANDEZ, R. J. KEMPER, C. F. KING, J. H. KIRCH, H. B. LEWIS, W. D. LOVELL, T. S. STONE, R. D. WHITE.

Your committee presents as information the following status report on the various projects it is now working on:

1. Types and Characteristics of Commonly Used Railroad Herbicides

The committee is making a list of chemicals now being extensively used on railroads, with pertinent properties, toxicological information, rates of application, and other useful information. As a separate topic under this project, we shall also furnish detailed information on brush and current methods of chemical control of the major brush species.

2. Spray Equipment: Techniques and Practices

Your committee is making a list of equipment now in use by railroads for vegetation control. We shall furnish general data and recommendations for use of equipment in varied situations for both mechanical cutting and chemical spraying. Included in this project will be various techniques and practices which have been successfully used; particularly, spraying with different types of nozzles, booms, etc.

3. Asphalt, Impregnated with Herbicide, for Erosion Control at Bare Ground Locations

This is a study of the use of asphalt impregnated with herbicides for weed control at locations where erosion becomes a problem when vegetation is removed.

Your committee has long been interested in erosion problems which occur when vegetation has been removed, particularly at bridge ends. At present, one railroad, cooperating with your committee, is experimenting with the use of asphalt emulsion impregnated with a soluble form of a residual herbicide.

Report of Committee 3—Ties and Wood Preservation

°K. C. Edscorn, *Chairman*
°W. F. Arksey, *Vice Chairman*
°R. G. Zietlow, *Secretary*
°C. S. Burt

°E. M. Cummings
°W. W. Barger
°L. C. Collister
°J. T. Slocomb
°P. D. Brentlinger
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R. S. Belcher (E)
C. P. Bird
G. B. Boggs
G. W. Brenton
R. G. Brohaugh
W. Buehler (E)
C. A. Burdell
C. M. Burpee
R. E. Case
D. L. Davies
T. J. Delaney
H. R. Duncan (E)†
M. S. Edwards
D. E. Embling
F. J. Fudge
W. E. Fuhr
J. K. Gloster
H. M. Harlow
F. F. Hornig
M. S. Hudson

R. P. Hughes (E)
W. R. Jacobson
H. F. Kanute
L. W. Kistler (E)
M. A. Lane
T. F. Maloney
H. C. Martin
J. J. McManus
W. G. Merritt
C. S. Morton
G. H. Nash
L. M. Nichols
T. H. Patrick
R. B. Radkey
H. E. Richardson
H. S. Ross
Rudi Rotter
J. T. Skerczak
O. W. Smith
R. B. Smith
G. H. Way
R. C. Weller
F. M. Whitmore
J. L. Williams
H. K. Wyant
Committee

(E) Member Emeritus.
† Died Oct. 24, 1967.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 3.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
Progress report, submitted as information . . . . page 533

2. Cross and switch ties.
(b) Extent of adherence to specifications for cross and switch ties as observed on field inspection.
Progress report, submitted as information . . . . page 533
(e) Possible revision of cross tie design and/or spacing, collaborating with Committee 5.
Progress report, submitted as information . . . . page 533

3. Wood preservatives.
(a) Keep up to date specifications for preservatives.
Progress report, submitted as information . . . . page 534
(b) New preservatives.
Progress report, submitted as information . . . . page 534

4. Preservative treatment of forest products.

   (a) Keep up to date specifications for treatment.
   Manual revisions submitted for adoption were published in the Manual Recommendation Supplement to Bulletin 610, December 1967.

5. Service records of forest products.

   (a) Annual tie renewal statistics as furnished by the Bureau of Railway Economics, AAR.
   Progress report, submitted as information .... page 534

   (b) Marine organisms.
   Progress report, submitted as information .... page 535

   (c) Service test records of forest products used in railroad construction and maintenance.
   Progress report on termite control investigation, presented as information .... page 536
   Progress report on B&O test of treated wooden cross ties, presented as information .... page 537

6. Collaborate with AAR Research Department and other organizations in research and other matters of mutual interest.
   Progress report, submitted as information .... page 542

THE COMMITTEE ON TIES AND WOOD PRESERVATION,
K. C. EDSCORN, *Chairman.*

AREA Bulletin 612, February 1968.

Report on Assignment 1

Revision of Manual

C. S. Burt (chairman, subcommittee), W. F. Arksey, K. C. Edscorn, D. E. Embling, W. E. Fuhr, R. P. Hughes, H. F. Kanute, M. A. Lane, C. A. Peebles, O. W. Smith, R. B. Smith, J. L. Williams.

Recommendations for Manual changes have been made by Subcommittees 3 and 4.

Report on Assignment 2

Cross and Switch Ties

E. M. Cummings (chairman, subcommittee), W. F. Arksey, C. P. Bird, G. B. Boggs, P. D. Brentlinger, K. C. Edscorn, F. J. Fudge, J. K. Gloster, F. F. Hornig, W. R. Jacobson, H. F. Kanute, M. A. Lane, T. F. Maloney, G. H. Nash, H. S. Ross, R. C. Weller.

EXTENT OF ADHERENCE TO SPECIFICATIONS FOR CROSS AND SWITCH TIES AS OBSERVED ON FIELD INSPECTION

In May 1967, 14 members of Committee 3 inspected cross and switch ties at a treating plant in Springfield, Mo. The plant was found to be neat and clean, with generally good drainage. Ties were stacked well for seasoning. However, ties below standard were included in the same stacks and were to be removed before treatment.

Ties inspected were mostly white or red oak, with some pine, gum and mixed hardwoods. Quality of ties was good, and no anti-splitting devices were used.

Adherence to size specification was good. Tie sizes are based upon the standards of the railroad, which closely follow AREA recommendations. The ties were marked for size by stenciling.

POSSIBLE REVISION OF CROSS TIE DESIGN AND/OR SPACING (STANDARDIZATION OF CROSS TIES)

As information, your committee reports that a survey of several railroads indicated that wood cross tie spacing varies from 19½ to 23 in center to center for main-line track, and from 21 to 24 in for side tracks.

Several railroads have installed test sections of wood ties, using other than standard sizes. However, it is too early to obtain results of these tests. The Association of American Railroads' Research Department is also studying cross tie size and spacing, and its findings should be available in the near future.

Report on Assignment 3

Wood Preservatives

W. W. Barger (chairman, subcommittee), W. F. Arksey, A. B. Baker, R. C. Brohaugh, C. A. Burdell, D. L. Davies, R. F. Dreitzler, K. C. Edscorn, W. R. Jacobson, J. J. McManus, L. M. Nichols, T. H. Patrick, O. W. Smith, H. K. Wyant, R. G. Zietlow.

KEEP UP TO DATE CURRENT SPECIFICATIONS FOR PRESERVATIVES

Your committee has made changes in the specifications for preservatives in Chapter 17 of the Manual in order to bring them up to date with the same specifications of other national organizations. Many of these changes were editorial and others were minor changes that help to more nearly describe the preservative.

The revised specifications were published in the Manual Recommendation Supplement to Bulletin 610, December 1967.

In that same supplement your committee also recommended the deletion of two salt preservatives due to their decline in use; namely, copperized chromated zinc chloride (CuCZC), and chromated zinc arsenate (CZA).

NEW PRESERVATIVES

Your committee also submitted for adoption a new preservative, solubilized copper-8-quinolinolate. This preservative has a limited use but we feel that it should be included in our list of salt preservatives. It is approved specifically for the treatment of wood which might come in contact with foodstuffs.

Report on Assignment 5

Service Records of Forest Products

J. T. Slocomb (chairman, subcommittee), W. F. Arksey, A. B. Baker, K. C. Edscorn, M. S. Edwards, F. J. Fudge, H. M. Harlow, R. P. Hughes, R. B. Radkey, J. L. Williams.

ANNUAL TIE RENEWAL STATISTICS AS FURNISHED BY THE BUREAU OF RAILWAY ECONOMICS, AAR

The 1966 statistics compared with those of 1965 are as follows:

Year	*Total New Tie Renewals*	*Renewals per Mile*
1965	*14,284,674	47
1966	**14,903,484	49
Five year average, 1962 to 1966, incl.		44

* Includes 4,841 concrete ties.
** Includes 32,409 concrete ties, excludes 442,388 secondhand ties.

The average cost of a treated wood tie was $4.08 in 1965 and $4.25 in 1966. As noted in the tables published in Bulletin 607, June–July 1967, these figures represent storekeeper's average cost of ties charged out; they are not the actual cost or prices paid for ties purchased during the period. The average cost of a concrete tie used in replacement was $12.11.

After declining for ten straight years (1951–1961), the average number of new ties laid in replacement advanced from 35 in 1961 to 49 in 1966.

Total ties replaced in 1966 were 15,345,872. Disregarding the wider spacing of concrete ties, this figure divided into the total number of cross ties supporting maintained track, indicates an average wood tie life of 59.2 *years*—still far above the actual average life of a treated wood tie.

Several railroads did not charge out secondhand ties in 1966 and their replacement figures do not show in the published tables. Hence, the calculated "average tie life" figure is not quite accurate.

MARINE ORGANISMS

Reginald H. Colley, technical director, Bernuth, Lembcke Co., Inc., New York, reported to the American Wood Preservers' Association at their 1967 Annual Meeting as follows:

"In cooler northern marine waters, where the hazard of Limnoria attack may be minor, creosoted piles have given long satisfactory service. Poor performance is frequently encountered under extreme exposure conditions in warmer southern waters. Experimental evidence from marine tests of treated blocks, panels and full-size piles has shown that neither coke-oven creosote nor creosote-coal tar solution in any practical concentration is an effective preservative against attack by Limnoria tripunctata. This evidence is supported by the results of laboratory tests using L. tripunctata and by extensive observation of treated piles in service in severe hazard locations. The marine and laboratory tests also indicate that, pending further investigation, a dual treatment with copper-chrom-arsenic or with copper-arsenic salts—to control L. tripunctata—followed by creosote at optimum retention—to control Teredo and Bankia—should result in significantly better performance under extreme exposure conditions than can be expected from the use of either creosote or creosote-coal tar solution alone. Dual-treated southern pine and Douglas fir piles, installed at several locations in tropical and sub-tropical waters, are under observation."

And on the same subject, Dr. R. H. Baechler of the U. S. Forest Service Forest Products Laboratory reported in 1967 as follows:

"In 1959 we treated panels of two sizes and arranged for their exposure in harbors at Los Angeles; Wrightsville Beach, N. C.; Port Hueneme, Calif.; and Pearl Harbor. Some panels were treated with copper arsenate and some with nickel arsenate by the double-diffusion method. The nickel treatment was less effective and will be disregarded in the remainder of my letter. Some panels were treated by double diffusion and then dried and pressure treated with creosote. Others were treated with creosote alone. The results have shown a similar pattern in each harbor. The creosoted panels have failed first, failure in all cases being due to Limnoria attack. Double-diffusion-treated panels have remained free from attack for a longer period but ultimately are attacked by Teredo. Panels treated by double diffusion followed by creosoting have so far resisted both Teredo and Limnoria. Of the ⅜- by 1½- by 5-in panels exposed for 7 years at Pearl Harbor, none has failed as yet, but after 6 years Martesia attack was observed. Panels treated with creosote alone were destroyed in 44 months. Since the salt-plus-oil-treated panels contain an insoluble, inorganic, copper-arsenic compound, the results certainly have more than a slight bearing on the double treatments being considered by the wood-treating industry."

TERMITE STAKE TEST—REPORT OF JANUARY 1967

Purpose of the Test—This is a 15-year investigation to determine the most effective preservative in retarding decay and termite attack. The test involves 13 well-known preservatives at three levels of retention on three species of wood (oak, fir, and pine). Wood samples are 2 x 4 x 18 in stakes set into the ground for half their length in a humid forest setting near Gainesville, Fla. In this situation, any of the three species will either rot or be consumed by termites in one to four years without treatment.

Those in attendance at the field investigation in January of 1967 were K. C. Edscorn, A. B. Baker, and J. T. Slocomb from AREA and E. J. Ruble and I. A. Eaton from the AAR Research Center.

AAR Report No. ER-73 gives a complete account of the entire test at 112 months of exposure.

Although it is early in the investigation for definite results, trends are developing which are interesting to note.

The accompanying chart attempts to summarize the important results to date. A check mark indicates that a grouping (same species, retention, and preservative) has an average index of "75" or better at 87 months of exposure. This means the average of the stakes in this grouping has only superficial decay and/or slight termite attack. Although the entire test is 112 months old, the creosote tars and creosote petroleums have only been in place 87 months. In order to compare performance, the latter number of months had to be used (7 years, 3 months.)

Drawing information from the chart:

1. Coal tar creosote is the only preservative maintaining this high level of performance for all species at all levels of retention.

Comparison of Preservatives and Species with an Average Index of "75" or better at 87 months exposure	Coal Tar Creosote	Chromated Zinc Chloride	*Tanalith (Wolman)	Pentachloro Phenol	Copper Naphenate	Acid Copper Chromate (Celcure)	Ammonical Copper Arsenite (Chemonite)	Chromated Zinc Arsenate (Boliden)	Chromated Copper Arsenate (Greensalt)	Creosote - Coal Tar 60 - 40	Creosote - Coal Tar 80 - 20	Creosote - Petroleum 50 - 50	Creosote-Petroleum 25 - 75		
Retentions & Species															
Low Retentions															
Oak	X														
Fir	X						X			X	X	X			
Pine	X									X	X				
Average Retentions															
Oak	X			X											
Fir	X				X	X	X			X	X	X	X		
Pine	X				X		X			X	X	X	X		
High Retentions															
Oak	X			X	X	X			X						
Fir	X			X	X	X	X	X	X	X	X	X	X		
Pine	X			X	X	X	X		X	X	X	X	X		

*Tanalith =
Sodium Flouride
Arsenic
Phenol
Chromium Salts

2. Creosote coal tar 60–40 and 80–20 are holding at the "75" level or better in fir and pine at all three levels of retention. Not so, however, in oak—at any of the levels of retention. This is an important observation.
3. Tanalith and chromated zinc chloride are falling far short of the "75" level for all species and retentions.
4. "Penta" is providing this high performance for all species only under the highest retention. Medium retention meets the mark for oak alone.
5. Copper naphthanate is performing as above except reversed in the average retentions—"Yes" for fir and pine, "No" for oak.
6. Ammoniacal copper arsenate (chemonite) is holding at this "75" level at all retentions, except in oak where it is not making this mark at any level of retention.
7. Acid copper chromate (celcure) is holding this "75" mark with high retentions only, except in fir where an average retention is doing the job.
8. Chromated zinc arsenate (Boliden salts) is holding at this "75" level only under high retentions and only in fir.
9. Chromated copper arsenite (Greensalt) is holding at the "75" mark in all three species at the highest retention only.

BALTIMORE & OHIO RAILROAD TEST OF TREATED WOODEN CROSS TIES, GERMANTOWN TO BARNESVILLE, MD.

Purpose

In the years 1927 and 1928, a series of 49 test panels of treated wooden ties were inserted under double trackage between Germantown and Barnesville, Md. Some 23,394 ties were involved. All of the better known preservatives of that time (in several mixtures and proportions) more used in treating three species groups (in various retentions) to determine relative longevity.

The designers of this broad series of tests sought to determine the best preservative and retention for each species group. The outcome of the experiment could have an important bearing on the selection of the most economic cross tie treatment and species for B&O environment.

Design

A track straightening project between Germantown and Barnesville involved some six miles of double track under which all of the ties were to be renewed. This situation was ideally suited to a series of tests.

Air-dried, main-line ties, separated into three species groups, were treated at the Green Spring Plant with five different preservatives in various mixtures, proportions and retentions. Charge sheets and preservative analyses, describing the treatment in detail, were carefuly prepared and made a part of the test permanent rcords. In general, ties were seasoned ten months to a year and then treated by the Lowry process to desired retentions. Treating pressure was 175 psi and the temperature did not exceed 200 F. Ties were neither bored nor incised. All ties were S-Ironed upon arrival at the plant.

The treated ties, properly identified, were then moved to Germantown for insertion.

The first section begins under the eastbound track opposite the passenger station at Germantown and proceeds westward. The several panels continue through Boyds and on to a point just east of Barnesville at Valuation Station 1701—a distance of six miles.

The test sections then continue under the westbound track from Valuation point 1601 eastward to 1346—approximately 3,000 feet east of the beginning.

The preservatives, retentions and species are summarized in Tables 1, 2, and 3.

Conditions

Below is listed important information relative to physical and environmental conditions influencing average useful life of the ties:

1. Grade: — 1% to + 1%
2. Rail: 131 lb
3. Curvature: Not over 1 deg 19 min
4. Plates: 8 by 12 in, three and four hole
5. Traffic: 12,500,000 tons per year west bound; 12,800,000 tons per year eastbound
6. Precipitation: 33 in annually.
7. Temperature: Minimum winter, 0 F; maximum summer, 98 F
8. Ballast: Fairly clean stone, evenly tamped and well drained except in areas of 50/50 and 70/30 creosote-coal tar panels
9. Soil: Red clay and shale
10. Latitude: 39°12′, Longitude: 77°20′
11. Elevation: 580 ft

Results

Since the year 1930, annual visits have been made to the test area. Records have been kept showing the number of ties in place, their general condition, and the average life of the ties in each panel to date.

Table 1, 2, and 3 summarize this information as of the year 1966—38 years after insertion.

Some facts are now being revealed. The varied nature of the wood within the same species, drainage, support, minor derailment damage, and other conditions affect the results so that the remaining number of ties are not an absolute reflection of the merits of the various preservatives and species.

Conclusions to be Drawn from the Germantown Tie Test After 38 Years of Continuous Observation

1. With every preservative tested, the mixed hardwoods are outlasting the oaks from one to 12 average years.

2. After 38 years, 15 out of the 18 preservatives tried on red oak have now failed; 11 out of the 16 preservatives tried on white oak have now failed; only *1* of the 15 preservatives tried on mixed hardwoods have now completely failed.

3. The various species of mixed hardwoods rated in order of their ability to maintain gage and surface at 38 years of age are as follows: locust, walnut, hard maple, hickory, birch, beech, elm, ash, cherry and hackberry. Soft maple and sycamore seldom reach a service age of 38 years.

4. The best preservative among those tested for mixed hardwoods appears to be an 8-lb treatment of creosote-tar 60–40. Average life to date is 32.2 years. Indicated average life is 37 years.

5. The best preservative among those tested for white oak seems to be a 5-lb treatment of creosote-tar 50–50. Average life to date is 24 years. All the ties in the test are now out.

(Text continued on page 542)

Table 1—Red Oak

Germantown to Barnesville, Maryland

Duration of Test - 38 Years

Report for 1966
Renewals
Installed in Summer of 1928

Red Oak Code		Treatment	Ties Placed	In Test	To Date Removed No.	%	Average Life To Date	Condition	Indicated Average Life
1	8#	Creo-Pet 50-50	300	0	300	100	20.4*	Deep, multiple checks Splits, decay, crush, crumble	
2	9#	Creo-Pet 50-50	900	0	900	100	25.1*	Same, spike, kill	
5	9#	Creo-Tar 50-50	900	223	677	75	25.3	Same	28
8	10#	Creo-Tar 60-40	900	117	783	87	23.3	Same, knots rot out first	27
11	8#	Water-Gas Tar 100%	900	0	900	100*	17.3*		
14	9#	Creo-Pet-WG Tar 30-30-40	900	0	900	100*	18.9*	All gone	
19	8#	Creosote 100%	900	0	900	100	20.3*	All gone	
20	8#	Creo-WG Tar 50-50	900	0	900	100	20.8*	All gone	
23	9#	Creo-WG Tar 40-60	900	0	900	100	20.0*	All gone	
26	10#	Creo-WG Tar 30-70	900	0	900	100	20.9*	All gone	
29	8#	Creo-Pet-WG Tar 30-50-20	900	0	900	100	21.6*	All gone	
32	10#	Creo-Pet-WG Tar 40-30-30	900	0	900	100	21.2*	All gone	
35	6#	Creosote 100%	900	0	900	100	21.1*	Crumble, check, split, crush, decay	
36	.47 3.75	Zinc Chloride Petroleum	600	0	600	100	15.6*	All gone	
37	.318 4.70	Zinc Chloride Petroleum	600	0	600	100	16.1*	All gone	
39	10#	Creo-Tar 80-20	900	30	870	97	26.0	Same as above	26.5
42	9#	Creo-Tar 70-30	900	0	900	100	23.8*	All gone	
47	9#	Creo-Pet 40-60	900	0	900	100	22.2*	All gone	

Red Oak Characteristics after 35 Years — *- Test Completed

Deep, frequent checking along wood rays.
Splitting, surface, crumble, plate cutting. Knots rotted. Decay working back within center of tie from checks and from spike holes. At least one-half of these ties should now be replaced - no gauge or surface holding.

Table 2—White Oak

Germantown to Barnesville, Maryland

Duration of Test - 38 Years

Report for 1966
Installed in Summer of 1928

White Oak Code		Treatment	Ties Placed	In Test	Removed To Date No.	%	Average Life To Date	Condition	Indicated Average Life
4	5#	Creo-Tar 50-50	300	0	399	100	24.0•	Surface crumble,slit diffuse checks,crush, rot	
7	7#	Creo-Tar 60-40	300	61	239	79	23.5	Same	24.5
10	7#	Water Gas Tar 100%	300	0	300	100	20.0•	Same	
13	7#	Creo-Pet-WGT 30-30-40	300	0	300	100	21.8•	Same	
16	6#	Creosote 100%	300	0	300	100	19.8•	Same	
18	8#	Creosote 100%	300	0	300	100	21.1•	Same	
21	8#	Creo-WG tar 50-50	300	0	300	100	21.0•	Same	
24	7#	Creo-WG tar 40-60	300	30	270	91	21.8	Same. Knots rot early Spike kill, interior decay	22.5
27	8#	Creo-WG tar 30-70	300	48	252	83	23.1	Same	24.3
30	5#	Creo-Pet-WG 30-50-20	300	0	300	100	20.5•		
33	7#	Creo-Pet-WG 40-30-30	300	11	289	96	23.5	Same	24
38	.41 2.82 #	Zinc Chloride Petroleum	300	0	300	100	19.0•		
40	7#	Creo-Tar 80-20	300	11	289	96	23.5	Same	24
43	7.5#	Creo-Tar 70-30	300	0	300	100	26.3•		
45	7#	Creo-Pet 50-50	300	0	300	100	22.7•		
48	7#	Creo-Pet 40-60	300	0	300	100	22.4•		

White Oak - General Characteristics after 36 years   •- Test Completed

Deep, multiple radial checking and splitting.
Crush rail seats.
Decay working back within center of tie from spike holes and deep checks.
Surface crumble from preservative leaching - not quite as severe as red oak.
V-coring.
From 1/2 to 1/3 of the ties now in place have ceased any function of holding surface and grade. Should be replaced.

TABLE 3—MIXED HARDWOODS

Germantown to Barnesville, Maryland

Duration of Test - 38 Years

Report for 1966
Installed in Summer of 1928

Hardwoods Code	Treatment	Ties Placed	In Test	Removed To Date No.	Removed To Date %	Average Life To Date	Condition	Indicated Average Life
3	8# Creo-Tar 50-50	300	84	216	72	31.5	Sp.,Ch.,good for age Firm	34
6	8# Creo-Tar 60-40	300	223	77	25	32.2	Hd.Map.,Hick,Ash good Firm	37
9	8# Water Gas Tar 100%	300	0	300	100	20.4*	All gone	
12	10# Creo-Pet-WGtar 30-30-40	300	134	166	55	27.2	Some surface crumble Sp., Ch.	32
15	7.6# Creosote 100%	300	63	237	78	23.1	Good for Age,Sp.,Ch Firm	26
17	8# Creosote 100%	300	77	223	74	26.0	Same	28.5
22	8# Creo-WG tar 50-50	294	58	236	80	23.9	Same-Maple,Hickory are outstanding	26.9
25	9.5#Creo-WG tar 40-60	300	71	229	75	25.0	Few beech with decay within	27.5
28	10# Creo-WG tar 30-70	300	42	258	86	23.2	Sp.,Ch.Good Hickory Locust excellent	25
31	9# Creo-Pet WGtar 30-50-20	300	75	225	71	28.0	Ash,hick,H.Map-this order	31
34	9.5# Creo-Pet WGtar 40-30-30	300	46	254	85	24.2	Same	25.9
41	9# Creo-tar 80-20	300	52	248	82	28.5	Good - Sp., Ch.	30
44	7.5# Creo-tar 70-30	300	38	262	87	27.5	Same	30
46	8# Creo-Pet 50-50	300	40	260	87	27.5	Beech is plate cut All in underbridge	30
49	9# Creo-Pet 40-60	300	42	258	86	26.1	Good Hickory and Hd. Maple	29

Mixed Hardwood- General Characteristics after 36 years   *- Test Completed

Some checking and splitting.
Hardwoods seem firmer in old age. Less fine meduallary checking.
Less surface leaching.
Splitting and checking is not as deep and not as frequent as in the oaks.
Except in beech, not as much interior decay as in oaks.
Species listed in order of condition at 36 years of age - hard maple, ash, cherry, gum, birch, beech. A few locust are best of all.

6. The best preservative of those tested on red oak appears to be a 9-lb treatment of creosote-tar 50–50. Average life to date is 25.3 years. Indicated average life in 28 years.

7. Because of their nakedness, all old ties seem to be suffering from weathering —especially the wide-rayed, big-pored oaks.

Report on Assignment 6

Collaborate with AAR Research Department and Other Organizations in Research and Other Matters of Mutual Interest

P. D. Brentlinger (chairman, subcommittee), W. F. Arksey, R. G. Brohaugh, M. C. Davidson, T. J. Delaney, K. C. Edscorn, M. S. Edwards, H. M. Harlow, F. F. Hornig, H. C. Martin, W. G. Merritt, C. S. Morton, R. B. Radkey, H. E. Richardson, H. S. Ross, Rudi Rotter, J. T. Skerczak, G. H. Way, H. K. Wyant.

SUBSTITUTES FOR WOOD TIES

Laminated Wood Ties

The Canadian National Railways reports that it has purchased 3,000 laminated cross ties to be installed in its Edmonton Terminal Project, and Yale Subdivision in British Columbia. It is interesting to note that the ties will be installed on 23½-in centers. Lodgepole and Ponderosa pine, with a small amount of fir, was laminated to produce Grade 1 ties with dimensions of 6⅞ in by 9¾ in by 8 ft. The laminates were 2⅛ in and 2⅜ in thick. Canadian National Railways' Specification (tentative, September 1966) for Grade 1 Laminated Soft Wood Track Ties was used. This specification details the manufacture and quality of the component parts, and the glue and glueing. The ties will be treated with 50/50 creosote-petroleum to a final retention of 7 lb per cu ft of wood.

New Patents for Substitute Ties

Two patents, issued December 6, 1966, for wood–tie substitutes have come to attention of the committee. Patent 3,289,940 is for a synthetic railway tie. This tie is patented for several shapes of ties, and also for two methods of attaching the rail to the tie. The patent also covers a reinforced synthetic tie. The composition of the tie includes many combinations of synthetic resinous materials.

Patent 3,289,941 was issued for "Railway Track Without Ballast." This invention claims to arrange the track in such a manner as to avoid use of ballast without affecting the resilience of the track. The system provides a railway track comprising a continuous platform overlying the substructure. The inventor used the two-block concrete tie in his illustrations as a part of the system. The title of the patent is Railway Track Without Ballast, but the patent primarily appears to be adapted to tunnels.

Status of Specification for Concrete Ties

The specification for concrete ties commands the principle attention of the subcommittee. Field observations and repeated tests have caused many changes from the original Tentative Recommendations for Prestressed Concrete Ties and Fastenings published in AAR Report No. ER-58, dated April 1965.

In view of the fact that several kinds of concrete ties are being offered the American railroads, the committee decided to write a performance specification that any concrete tie would be required to meet. We can only report progress at this time.

Inspection of Concrete Ties on the Frisco

The following is an account of an inspection of concrete ties on the St. Louis–San Francisco Railway near Cabool, Mo., in October 1967. These ties were installed in October 1962 and last inspected previously in October 1964.

Type and Number of Ties:

Type "E"—Direct Fixation with polyethylene pads and uniclips—1054.

Transverse Cracks:	*1964*	*1967*
(1) Center portion of tie:		
Number of ties with cracks	748 (71%)	938 (89%)
Total number of cracks	1112	1667
(2) End portion of tie—Bolt holes:		
Total number of cracks	36 (3.4%)	63 (6%)
(3) End portion of tie—Grooves:		
Total number of cracks	3	4

Longitudinal Cracks:

Only tie No. 1034 had a longitudinal crack which had existed since bolts were tightened during installation in October 1962. However, by October 1964 this crack had lengthened to 45 inches in length from the end of the tie toward the center where it connected with a transverse crack. The October 1967 inspection revealed no change in this.

Torque on Bolts:

During the October 1964 inspection, bolts in the following ties were checked with a torque wrench; 1 to 10 incl., 1050 to 1054 incl., and every tenth tie 20 to 1040 incl., for a total of 472 bolts in 118 ties. Findings were as follows:

Torque Required to Turn Bolt in Tightening Direction (Ft Lb)	*No. of Bolts*	*Percent*
Over 185	180	38.1
155 to 180	154	32.6
100 to 150	125	26.5
60 to 95	9	1.9
0 to 50	4	.9

The October 1967 inspection revealed that all the original bolts in this installation had been removed and replaced with new bolts during August and September 1967 due to extreme rusting of the bolts from brine and atmospheric corrosion. The rusting was on the shanks of the bolts between the threads and the heads, i.e., the area that is exposed. The main area of rust deterioration of each bolt was immediately above the threaded insert of the tie where this particular design of tie has a ½-in-deep recess wherein water and foreign material can lodge. The new bolts were checked with a torque wrench in a manner like that in the 1964 inspection and the findings were as follows: (Note—400 bolts in 100 ties were checked)

Torque Required to Turn Bolt in Tightening Direction (Ft Lb)	*No. of Bolts*	*Percent*
Over 185	1	0.25
155 to 180	30	7.5
100 to 150	338	84.5
60 to 95	23	5.75
0 to 50	8	2.0

The bolts were originally torqued to 120 ft-lb in October 1962, and it can be noted that the greatest percentage of the original bolts rusted or froze to a higher torque as revealed in the 1964 inspection. The new bolts installed in 1967 were also torqued to 120 ft-lb, and it can be noted that 84.5 percent retained this torque, with a small percentage gaining or losing torque in only 1 month.

Miscellaneous:

In 1964, nine pads between the rail and concrete tie were showing some displacement by slewing. The October 1967 inspection revealed that 18 pads were slewing and 7 were slewed and broken.

During the 5-year period that these ties have been in track, the following ties have been removed for the reasons noted:

Ties 605, 642 and 657—removed for testing at AAR and PCA laboratories, August 1965.

Tie 220—removed on account of failure in rail seat area, March 1967.

Ties 201, 210, 211, 218 and 262—removed on account of failure in rail seat area, October 1967. (Some ties pumping, three of the five were at insulated rail joints.)

Ties No. 690 and 795 were noted to be cracking and failing in the rail seat area and should be removed soon. All other ties, even those with transverse cracks in center portion and through bolt holes in rail seat area, as noted, are in good condition; 108 ties have no cracks.

Because of the failures of some ties as noted above, and assuming that some of these failures were due to ties pumping in the ballast, the railroad surfaced the concrete tie section of track in April of 1967. At the time of the inspection in October 1967, it was noted that several ties were again pumping in the ballast, thus the surfacing of the track did not cure this condition. The railroad records show that since the installation in October 1962, the concrete tie section of track has maintained very good line, level and track gage. This portion of the railroad has 132-lb welded rail. Two insulated joints at a signal location are within the confines of the concrete tie section.

Experience of the Frisco with Prestressed Concrete Cross Ties*

By O. E. FORT

Chief Engineer, St. Louis—San Francisco Railway

Concrete cross ties are not new; their first recorded use in the United States was in 1893 by the Reading Company. Between that time and World War II over 150 types of conventionally reinforced concrete cross ties were designed and patented. Over 50 railroads made test installations during this period and found the reinforced concrete ties inadequate due to improper design or unsatisfactory rail fastenings.

After World War II European railways were generally in need of major overhauling due to extensive war damage and the scarcity of men and material for proper maintenance during the war. Because of the scarcity of suitable timber for ties, various countries in Europe turned to the possible use of concrete ties as a substitute for wood ties. This was during a period when several European countries were successfully designing and constructing more and more prestressed concrete structures. Generally speaking, it soon became apparent that some type of prestressed concrete tie would be the most economical substitute for the timber tie, and various European countries designed, manufactured and tried out various designs of prestressed concrete ties. With improvements in design, prestressed concrete ties have continued to be used on the railroads in Europe.

The first major service test of prestressed concrete cross ties in the United States was made in 1960 on the Atlantic Coast Line Railroad and the Seaboard Air Line Railroad. These tests indicated that prestressed concrete cross ties could possibly be used as a substitute for timber ties in a railroad main line from the standpoints of economics and service requirements.

Early in 1962 it was decided to install a test section of prestressed concrete ties on the Frisco. We selected a location near Cabool, Mo., on one of our main-line subdivisions which has 15 million gross tons of traffic per year. The test location is in an area where we have 132-lb welded rail and train speeds of 70 mph for passenger trains and 55 mph for freight trains. This test location is ½ mile in length and includes both tangent and curved trackage. The ½ mile of prestressed concrete ties is flanked by a ½-mile installation of new timber ties on each end of the prestressed concrete tie location. The timber ties were installed at 22½ inch centers to provide a bearing on the ballast equal to the concrete ties which were installed on 30-inch centers. It was felt that this would give us a good, comparative test of surface, line, maintenance requirements and tie life over a long period of time.

The prestressed concrete ties were shipped in gondolas and unloaded work-ways on the shoulder with a derrick and work train. The ties were unloaded three at a time, properly spaced, so that additional handling was not required prior to insertion. The ties in this test location were installed with a 9-man gang using two cribbing machines, a rail lifter, a tie inserter and two power wrenches. Production on this out-of-face installation varied from 70 to 120 ties per day. After installation of all test ties, the entire location was surfaced and lined with conventional on-track roadway machines.

* Address presented before the Third Regional Meeting of the American Railway Engineering Association, Dallas, Tex., November 7, 1967.

Since installation of this test section, most of the prestressed concrete ties have developed hairline cracks across the top in the center section. During installation we found two defective ties; in one the threaded inserts which are cast in the tie were involved, in the other, slippage of one of the prestressing cables occurred during manufacture. In addition, we have had three prestressed concrete ties fail due to breakage caused by dragging equipment. A record of maintenance costs as well as surface and line data is being kept on this test installation. In addition, the AAR Research Center has and continues to run tests on this installation.

The test installation of prestressed concrete ties, along with the comparative test installation of timber ties, convinced us that there is no particular answer as to which tie is the most suitable or which tie is the most economical. As far as suitability is concerned, each type of tie has advantages and disadvantages, and we feel that their relative economy will always be questionable until the life span of prestressed concrete ties is established.

We feel some of the advantages of the prestressed concrete ties are as follows:

1. Can be mass-produced on short notice.
2. Better quality control due to manufacture under one roof.
3. More uniform in quality.
4. Increased track modulus.
5. Better electrical insulation for signalling.
6. More fire resistant.
7. Less number of ties required per mile.

While some of the advantages of the timber tie are as follows:

1. Have historically proven to be satisfactory.
2. More flexible.
3. More easily handled.
4. Predictable length of life.
5. Less damage in derailments.
6. Our track people are experieneed in their use.
7. Present tie-inserting equipment is designed for the timber tie.

Local factors such as policy, location, time element, and economics will become the governing factor as to which type of tie is best for a particular project.

The Frisco has just completed the construction of a new 33-mile branch line in Missouri using prestressed concrete ties. This is the largest out-of-face installation of prestressed concrete ties in the United States. This new line serves a new mining area being developed in Iron and Reynolds County, Missouri, which is approximatly 130 miles southwest of St. Louis. This is in Ozark county, a region of rolling mountains, large oak-pine forests, small communities, and until recently a shrinking population and a declining economy. Various large mining companies through exploratory test holes have found deposits of iron ore, lead, zinc and copper. St. Joseph Lead Company and other great mining companies, including American Metal Climax and Homestake Mining Company—Cominco Limited of Canada and Dresser Industries—Kennecott Copper and American Smelting and Refining Company—American Zinc Company of St. Louis now own enough ore deposits in this area to guarantee the entire country's lead needs for many years to come. According to the Canadian Mining and Metallurgical Bulletin, these deposits give Missouri world prestige in this field.

Early in 1964, using simple auto reconnaissance and the available topographic information on the area—U. S. Geological Survey quad sheets with 20-ft contour intervals—a preliminary cost estimate was made which indicated it was economically feasible to serve this mining area by construction of a new line. On August 27, 1965, the Frisco announced it would begin construction of such a line. Within a few weeks, $79,000,000 in new investments in mines, mills and smelters were committed by the various mining interests. At this time planning began in dead earnest, with the time element being of extreme importance. We engaged the Surdex Corporation to prepare an aerial map of the proposed route on a scale of 1 in. = 200 ft with 5-ft contour intervals; 200 aerial photos developed 21 strip maps covering an area ½ mile in width along the proposed route. With the refined information available from these contour maps, we were able to improve our alignment and update our estimate. While it was desirable to maintain high construction standards, the cost of the project was of great importance to the economic justification of this railroad. Alignment was kept compatible with that portion of the Salem Branch over which it would be necessary to operate to reach the new Lead Branch. The maximum grade was limited to 2%, compensated for curvature, and the maximum curvature was limited to 4° with the exception of one 5° curve. Sverdrup and Parcel prepared the plans and contract documents in accord with our specifications. The line involved two railroad bridges, one 237 ft long across Dry Creek and the other 294 ft long across Huzzah Creek. These bridges are of a deck-plate girder design with a maximum girder depth of 8 ft and a maximum span length of 75 ft. Both of these structures are approximately 50 ft above the ground and are designed for Cooper E 80 loading with diesel impact.

Our $6,500,000 new Lead Line was designed for cars having gross weight of 315,000 lb, and it is anticipated that the opening of this new mining area will generate 8,500 carloads of business yearly for the Frisco.

Grading for the new line was started in January 1966 by Peter Kiewit Sons of Omaha, Neb., and in May this firm was also awarded the bridge contract. The total grading involved 3¾ million cubic yards of which one million cubic yards was rock.

The track contract was let to Grosshans and Petersen of Maryville, Kan., in December 1966 and the main line was completed in September 1967. The track contract specified that the contractor was to furnish all labor and equipment with the railway company furnishing necessary track material, including ballast.

The topography of the country through the location of this 33-mile new railroad was rather virgin and rough. Access roads, both intersecting and parellel, were scarce, which presented us with a problem in the distribution of track materials, especially the concrete cross ties and the rail. The track construction consisted of cropped 112-lb rail, 36 ft 6 in long, laid on prestressed concrete cross ties and fastened by indirect-fixation rail clips bolted into metal inserts cast in the tie. Sub-ballast consisting of 3 in of limestone screenings was hauled in by truck from the nearby tailing piles of St. Joseph Lead Company. In addition to the sub-ballast, we have 15 in of graded chatt ballast which was shipped over our line from the Tri-State lead-zinc mining area.

Intially we used a siding at Keysville, near the starting point of the new construction, as a rail head for unloading and stockpiling all track material, including rail and concrete cross ties. From this siding the rail was loaded and hauled by truck on low-boy trailers via the closest intersecting road and thence over the new roadbed and distributed along the shoulder. The concrete cross ties were also loaded on a low-boy trailers and distributed on the shoulder of the roadbed, using a crane with an unloading jig that would handle four ties at once. Prior to rail laying, a crane with a special jig placed the ties, properly spaced, on the smoothed and compacted sub-ballast. The rail was then placed on the ties by rail-mounted crane with the installation of the rail clips immediately following. As the construction proceeded, the necessary sidings were completed and the track material and ties were shipped to these sidings, thereby keeping the truck haul to a minimum. All but one of the railroad sidings of this new line are constructed with prestressed concrete cross ties.

Ballast was delivered and unloaded in 45-car lots by work train in three 5-in lifts. After each unloading the track was jacked and tamped by power tamper. In order to prevent damage to the concrete ties, it was found that it was very necessary for the ties to be completely tamped after jacking before rail traffic could be resumed. We quickly found that if the track was jacked and not tamped, a center-bound condition would result. Then, we had broken ties when the next ballast train passed over this track. This problem was completely eliminated by tamping the ties each time the track was raised. The contract with Grosshans and Petersen provided that the railroad would make the finish surface and finish line. This was accomplished with our own forces using electronic tampers and mechanical liners using a wire lining device.

Why did we choose concrete ties for this new 33-mile Lead Line? The decision to use concrete ties stemmed partly from the fact that a large number of ties was involved. The Frisco is in an area where procurement of treated wood cross ties is fairly easy. However, the need for about 106,000 main-line timber ties for this project would have caused some displacement in our regular programmed maintenance work. Also, our ½-mile test section of prestressed concrete ties after four years of service had proved satisfactory enough to consider using concrete ties on the new line. The requirement of 70,000 prestressed concrete ties made it economically feasible for the American Concrete Cross Tie Corporation to set up a tie manufacturing plant at Kansas City, Mo., which for all practical purposes eliminated foreign line haul. Considering the engineering data of other railroads using prestressed concrete ties and our own first-hand information, it was estimated there was a savings of approximately 5% in favor of using prestressed concrete ties. However, availability still was the major factor in the decision to use prestressed concrete ties. The prestressed concrete tie is a manufactured product which can be produced in quantity on short notice. The fact that concrete ties are a manufactured product, can be mass-produced with the raw ingredients going in one end and a finished product out of the other end at one location under one roof permits greater and simplified quality control. In connection with the purchase and use of 70,000 prestressed concrete cross ties, we gained considerable knowledge in quality control as well as material handling. Quality control is, in our opinion, the most important item to consider when using prestressed concrete cross ties. It is necessary to set up specifications covering the standard items such as cost, delivery schedule, delivery location, stockpiling, inspection, method of payment, etc. In addition, it is necessary to set up specifications covering the design and manufacture of the prestressed concrete cross tie. It is necessary that these specifications not only produce a suitable product but also they must consider economic feasibility. Both the Frisco and the American Concrete Cross Tie Corporation made various tests not only on the prestressed concrete cross tie but also on the fastenings during the entire period of manufacture. We received very close cooperation from this corporation in making various changes and modifications during the manufacture of these cross ties. Test ties were taken from each 200 tie lot (one shift production), with these tests being made:

1. Bending moment test, 158,000 in-lb, without visible cracking. Should a crack appear at 148,000 in-lb or more, the tie was acceptable if a 158,000 in-lb load was sustained for 3 minutes.
2. Density of tie was to be 155.0 lb per cu ft with a tolerance of $\pm$ 1%.
3. Electrical resistance test was that no less than 4000 ohms resistance between bolt holes be measured for an acceptable tie.
4. Anchor test for restraining of tie fastenings. A static load of 18,000 lb and a torque of 200 ft-lb must not cause the anchor to yield when either force was applied.

During inspection of tie production the need for allowable tolerance of cross sectional dimensions became apparent. It was agreed to permit a plus ¼ in or minus ⅛ in on the thickness of the tie.

Familiarization with mass production techniques is a necessary conditioning for the tie inspector.

Once again I would like to stress that we feel where volume buying is concerned, quality control is extremely important and it behooves the buyer to be represented by a knowledgeable engineer in connection with quality control.

The timber cross tie has been with us a long time and will continue to be with us for a long time in the future. The ability of timber cross ties to do the job has been proven, while there are still many questions to be answered as far as prestressed concrete cross ties are concerned. However, the treated wood tie is not essentially a manufactured product, and from the time the log is cut, carried to a sawmill, sawed into cross ties, moved to a rail head or marshalling area, transported to a seasoning area and held until dry, moved into the retorts for pressure treatment, loaded on cars and sent out to the right-of-way, many months will elapse. Even with vapor drying, which adds to the tie cost, this represents a long chain of different kinds of services performed by different unrelated people in different locations. In the nature of things, it becomes inherently difficult to control the schedule and costs of these various services by the usual means and techniques generally available in conventional manufacture. This is an inherent situation; it is not a criticism of the people involved in producing treated timber ties. They have been working and are working for greater efficiency and cost control, but within the serious limitations I have cited.

In an era of scientific and technological change, railroad maintenance and engineering must keep pace, and it is necessary that we look in all directions in order to improve the physical as well as the economic position of our companies. This means improvement of present products and methods and investigation of new products and new concepts. This is what we feel the Frisco has done in our present venture with the prestressed concrete cross tie.

We have learned many things about prestressed concrete ties—both from our test section in the main line and from our new 33-mile Lead Line—and we are happy to share with you some of our experiences with these ties.

Maintenance Installation of Concrete Ties*

By H. E. RICHARDSON

Division Engineer, Seaboard Coast Line Railroad

When the use of concrete cross ties is being considered, the question always comes up as to how such ties could fit into any program for the maintenance of main track mileage of the American railroads as now constituted. The improvements being made constantly in design and manufacture of the prestressed concrete tie indicated that a study of this matter was now feasible and was needed to assist in answering many questions in our minds as to what might be encountered should it become necessary in the future to use, in part, a substitute tie in maintaining our railroads. Along with answers to these questions, additional information was needed on the economic feasibility of such a plan should a quality wood tie at a reasonable cost become unavailable in the quantity needed.

As in any study there were several approaches that could be given consideration. In order to give you some background and maybe explain a little of what was actually done in the installation of concrete cross ties in a maintenance program on the Seaboard Coast Line in April 1967, I will mention a few of the avenues that were considered and briefly describe our immediate thoughts regarding them.

1. Any segment of track could be completely stripped of wood ties in a number of ways and invested with all concrete cross ties. For our study this approach was not given serious consideration inasmuch as we already have short segments of main-line track under study with all concrete cross ties. Also, many usable wood ties would be recovered in this method, and it was felt that some of the life of the wood ties now in the track would be lost as it would not be economically feasible to relocate a wood tie from the immediate area if it only had some seven or eight years of life left.

2. Another approach would be to place a concrete cross tie at each location where a wood tie was to be removed from the track. This particular approach has some advantages in the initial installation but would require the relocating of the concrete cross tie in the future in order to obtain a uniform spacing and to obtain the economic advantages of the wider spacing possible with the wider base concrete tie. Our experience with other installations had indicated that shifting a concrete tie would probably lead to tension cracks in the center of the tie due to the pressure built up by surfacing material in checks, unless all surfacing material was removed from the checks prior to relocation.

3. A third approach, and the one chosen for our study, would be to determine a set pattern or location for each concrete tie that would be desirable upon completion of replacing all wood ties with concrete ties after several maintenance cycles. A maintenance program could be established in which a specific number of ties could be placed in their final locations in the first installation, with other cycled installations being controlled by future need of tie renewals.

* Address presented before the Third Regional Meeting of the American Railway Engineering Association, Dallas, Tex., November 7, 1967.

Under the plan chosen it was desired ultimately to have 16 concrete cross ties per 39-ft rail, or a spacing of 29¼ in. This plan offered more control of the planned study, and for our initial study it was decided to place four ties under each rail. By numbering the concrete cross ties that will ultimately be under each rail 1 through 16 and beginning each panel of concrete cross ties in the center of a joint, our plan was to progress our study by placing in the first installation ties numbered 1, 5, 9 and 13, which provided a concrete tie under each joint and the quarter points of each rail.

Two miles of main-line trackage between Jacksonville and Wildwood, Fla., were chosen for this first study. The main track in this area consists of 132-lb jointed rail on granite ballast with an average of 22 ties per rail laid new in 1947. This track has consistently carried a tonnage in excess of 20 million gross ton miles per year and the possibility for increased tonnage in any normal growth situation is considered good. Last year this line carried in excess of 27 million gross ton miles. The authorized speed on this line is 79 mph, with the particular segment of track restricted to 70 mph because it has two 2° curves with 6½ in elevation. It was desired on our part to include curved track in our maintenance study and this was an ideal location inasmuch as it was our plan to timber this trackage in early 1967. Initial marking indicated that 1,368 wood ties would normally be replaced in the timbering cycle.

It was desired to make this installation as nearly as possible a simulation of our regular timbering and surfacing program, therefore it was decided that concrete ties would be installed by our normal timbering force when it arrived at this segment of track in the regular program. The concrete cross ties were unloaded in advance of this timbering force with a crane and a four-man section crew, and each was placed on the roadbed opposite the predetermined point where it was to be placed. The most economical work force with the equipment available in the beginning was of necessity a matter of trial and error, as no experience with similar installations had been obtained.

A laborer was used to place rail free concrete cross tie clips on each concrete tie ahead of the operation. It was found that this not only boosted production; having the clips placed on the tie ahead of the operation provided a guide for centering the rail in the proper place for receiving the other two clips.

A laborer with a power spike-puller removed all spikes from the deteriorated ties to be removed, as well as from the reusable ties to be relocated to some other point.

One laborer with a power wrench was required to remove rail compression clips from the wood ties being removed from the track ahead of the operation. During the afternoon this laborer reapplied rail clips on remaining wood ties in the installation. It was decided for the purposes of our study that all rail anchorage would remain on the wood ties with the thought that at a later cycle the anchorage could be transferred from the wood ties to the concrete ties.

It was found that four laborers with a tie puller were required to pull out the deteriorated ties and the reusable ties being relocated from their immediate area.

A tie-spacer was used to redistribute ties in the immediate area of the location of the concrete tie. This equipment was made available to us immediately prior to actual installation and proved to be of great assistance in reducing the number of wood ties that needed to be actually taken from the track and relocated to other points in order to maintain a track structure with uniform strength. To respace the ties with this equipment required only one operator. The foreman had marked the rail ahead of the operation as to where ties were to be relocated, but it was found, that with some training, the machine operator with this equipment could perform this function as he approached each location where wood ties were to be respaced in areas of the predetermined location of the concrete ties.

Behind the tie-spacer we located a push car for use by three laborers who plugged the reuseable ties removed from the track and carried them forward and redistributed them where they were needed within the test track area to replace deteriorated ties not replaced by concrete ties.

One track machine operator and one laborer were used to scarify the tie bed and to pull in the new concrete ties and the wood cross ties that were being relocated.

It was found that six laborers were needed in our operation to clean the ties, apply the tie plates on redistributed wood ties, gage as necessary, place the tie pads on the concrete ties and apply the two additional required rail free tie clips.

One laborer using an impact wrench tightened the concrete tie clips to a predetermined torque with air taken from the automatic spiker.

A spikedriver was used to drive all spikes in the relocated wood ties with the exception of the anchor spikes.

One laborer using an impact hammer drove anchor spikes on each wood tie where required. Air was taken from the automatic spiker for this operation and the spikes were set by the six men cleaning the ties, applying tie plates, etc.

A power tamping jack with one machine operator was used to tamp all concrete ties as well as relocated wood ties prior to surfacing, which followed immediately.

While the ties were being installed, a 30-mph slow order was placed on this track. The track was surfaced by a surfacing gang with production equipment immediately after the tie operation and maximum speed was allowed at the close of each work day.

It was found through trial and error with the equipment available to us that the tie operation could best be handled with 18 laborers and four track machine operators, with a foreman, assistant foreman, roadway mechanic, cook and cook helper making up the balance of the gang. The surfacing gang personnel is not included in this summary.

Over a period of 11 days in the two-mile test section, 1,368 deteriorated ties were removed from the track, 1,190 reuseable ties were relocated and applied within the test area, and 1,077 concrete ties were installed, with an approximate on-track time of 50% of each work day. There were 245 reuseable ties removed and not needed to obtain reasonable spacing and were available for use at other points. In this study, including our trial and error method to determine the correct labor force required with equipment available, we have found that it cost some $4.66 per deteriorated tie removed in order to place the track in similar structural strength to adjacent track being timbered. This is some 3½ to 4 times the labor cost when renewing wood ties in a normal program on our property. It was felt after our first limited experience that the relatively high initial labor cost for such an operation could be considerably reduced by adjusting existing equipment available on the property, training of labor for such an operation and the development of new equipment for such purposes. The development of equipment to perform the following functions is needed and will greatly reduce the labor organization required at this time:

1. Jack rail up sufficiently to permit final cleaning of rail seat area and assist in placing of tie pads.

2. Provide nipper and centering arrangement to line insert holes to proper location.

3. Provide carriage for personnel to perform the above duties in addition to the placing of tie clips and bolts, including their tightening with attached impact wrenches.

Our initial observations also indicated that in a situation where the number of deteriorated ties might be greater than in the area chosen for our study, the unit cost would be further reduced as it would eliminate the necessity of relocating many reusable timber ties the cost of which we have found no way to recover.

Between the concrete ties installed there are normally four wood ties which would ultimately be replaced by three concrete ties to give us the spacing desired. As the track is observed in the future, a determination will be made as to the ideal placing of additional concrete ties in any segment based on panel strength of the track structure. This is being observed constantly, and there is a possibility that some future cycles of tie renewals can be eliminated if the relative panel strength of the track structure permits. This will have to be taken into consideration in determining the overall economy for the mixing of ties in any segment of track.

Our study can only be considered as a beginning at the present time. There appears to be no problem in mixing concrete ties in track with wood ties, but many factors are known to affect the unit cost of such an installation and will require further study and ingenuity in order to reduce costs. At the present time we are basically interested in the riding condition of the track after mixing the concrete ties with wood ties. The track in our study now rides well and compares favorably with an adjacent track timbered and surfaced this year. This will be observed closely in the future in order to evaluate how the quality of surface, alignment and gage will be maintained.

The question has been raised as to the economic justification for an installation such as the one made by us and described today. Our study was not designed to provide an answer to that question in the short time that has elapsed since the initial installation. The cost and the quality of materials of the various products involved will vary over a period of years, the tie condition of each segment of track will vary and the desired maintenance standard for each segment of track will vary. This along with other factors makes it mandatory that the use of any substitute ties be a continuing study, therefore economic justification will be dictated by details obtained by experience over a long range plan and study of the subject on each and every segment of the railroad where such consideration is being given to install such a tie.

(Note: Mr. Richardson illustrated his talk with some 23 slides, none of which is reproduced herein.)

Report of Committee 5—Track

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Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 5.

To the American Railway Engineering Association:

Your committee reports on the following subject:

1. Revision of Manual.
   Progress report, with recommended revisions to the Specifications for Low Carbon Steel Tie Plates, Hot Worked High-Carbon Steel Tie Plates, Soft Steel Track Spikes and High-Carbon Steel Track Spikes were published in the Manual Recommendation Supplement to Bulletin 610, December 1967.

2. Track tools, collaborating with Purchases and Stores Division, AAR. No report.

3. Standardization of trackwork plans, collaborating with Communications and Signal Section, AAR.
   The proposed revision to Article 7, Malleable and Ductile Iron Castings, of Appendix A-51, Page 5, of the Specifications for Special

Trackwork, and the proposed revision to Article 14, Bolts and Nuts, of Appendix A-59, Page 7, were submitted for adoption and have been published in the Manual Recommendation Supplement to Bulletin 610, December 1967.
Progress report, submitted as information .... page 557

5. Tie Plates, collaborating as necessary or desirable with Committees 3 and 4.
No report.

6. Hold-down fastenings, collaborating as necessary or desirable on concrete ties with Committee 3.
Progress report, submitted as information .... page 559

7. Effect of lubrication in preventing frozen rail joints and retarding corrosion of rail and fastenings.
Progress report, submitted as information .... page 559

9. Special requirements of track construction and maintenance due to operation of equipment with high center of gravity and/or hydraulically cushioned underframes.
Progress report, submitted as information .... page 563

10. Modern methods of heat treating carbon steel trackwork and repairing such trackwork by welding.
Final report, submitted as information .... page 564

12. Procedure and specification for, and economies to be derived from, building track by the panel method:

(a) Where track is to be newly constructed.

(b) Where track now laid in conventional staggered-joint construction is to be relocated from one point to another:

(1) To remain as paneled after relocation.
(2) To have its joints restaggered after relocation.

(c) Specifications, plans and procedures for prefabricating turnouts in a central shop.

(d) Methods of moving prefabricated turnouts from a central shop to point of use.

(e) Method of handling a prefabricated turnout at point of renewal or installation.

Your committee is progressing this study; however, it has not received sufficient information to justify a report.

THE COMMITTEE ON TRACK,
C. E. PETERSON, *Chairman*.

AREA Bulletin 612, February 1968.

Report on Assignment 3

Standardization of Trackwork Plans

Collaborating with Communications and Signal Section, AAR

C. J. McConaughy (chairman, subcommittee), C. R. Alberts, T. L. Biggar, E. H. Blank, J. R. Bowman, L. E. Brault, J. E. Campbell, K. L. Clark, J. W. Clarke, J. P. Collins, C. D. Davis, A. D. DeMoss, L. D. Freeman, C. L. Gatton, B. J. Gordon, V. C. Hankins, C. N. Harrub, E. C. Honath, B. J. Johnson, R. A. Kelso, L T. Klauder, R. E. Kuston, E. J. Lisy, J. G. Martin, T. D. Mason, P. R. Matthews, G. H. Maxwell, M. P. Moore, C. W. Morrison, T. C. Netherton, G. A. Payne, B. E. Pearson, C. A. Peebles, L. A. Pelton, G. H. Perkins, G. Perko, C. E. Peterson, S. H. Poore, J. A. Pollard, L. E. Porter, B. Post, R. P. Roden, J. M. Salmon, A. J. Schavet, R. N. Schmidt, V. M. Schwing, R. D. Simpson, G. R. Sproles, F. J. Swoboda, R. E. Tew, R. W. Tipper, A. C. Trimble, J. J. Vereen, K. H. von Kampen, I. V. Wiley, M. J. Zeeman.

Your committee submits the following report as information.

The proposed revision to Article 7, Malleable and Ductile Iron Castings, of Appendix A, page 5, of the Specifications for Special Trackwork has been submitted for adoption and inclusion in the Portfolio of Trackwork Plans and Specifications. The proposed revision to Article 14, Bolts and Nuts, of Appendix A, page 7, has also been submitted for adoption and inclusion in the Special Trackwork Portfolio.

A study is being conducted on the subject of possible improvement in the design of manganese steel insert frogs for the purpose of extending their life. This study will also cover determining the life of railbound manganese steel frogs before and after welding, widening the point, increasing the slope of the flangeway walls to reduce the flow of manganese, widening the throat of the manganese steel casting on the end, and developing specifications for the repair of manganese steel castings by welding in the field.

The railbound manganese steel frog study will also have an effect on guard rail design. Due to the increase of train speeds, the flare on the wings of both the rigid and spring-rail frogs and the flare on the guard rail are considered to be too short.

Present guard rail designs are being reviewed as it appears that the present AREA plan provides for too short guard rails.

The letter submitted to all chief engineers by R. R. Manion, vice president, Operations and Maintenance, AAR, citing various derailments that have occurred on spring-rail frogs was forwarded to Committee 5 for review. Our committee was assigned this subject to develop improvements in design and to reduce maintenance problems.

A thorough study was made concerning numerous details and changes in spring-rail frogs, and the AREA plan will be revised to include the following changes:

1. Change the two-tie base plate to a three-tie base plate for extra support and stability.

2. Lengthen the horns to extend from ½ in to ¾ in beyond the end of the hold-down, which will give additional hold-down pressure on the spring rail.
3. Lengthening the spring-rail from 13 ft 3 in to 14 ft 10½ in for an additional horn and hold-down box that will help to hold the spring-rail down. Also lengthen the base plate to accommodate the horn strap and hold-down box. This will give additional support to the frog.
4. Add ¼-in-deep grooving through spring-rail and long-point for false wheel flanges and lower the heel riser ¼ in below the top of long and short point, which will reduce the shock of the wheel striking the long-point and spring-rail, which should reduce the frog maintenance.
5. A more efficient operation of the spring frog will result from the short-coupled-design spring housing. This will reduce rolling of the spring wing rail.
6. Change the hooked twin tie plates for wide tie plates that are milled out for rail seats for better support.
7. Change ¾-in plate clips with ½ in opening over blocks on the base plate to a ⅝-in clip, which is stronger and less expensive.

The revised spring-rail frog plan will be submitted as Manual material in 1968.

A letter was received from Mr. Viberg of the Canadian Steel Foundries recommending that the AREA Specifications for Special Trackwork, Sections 408 and 409, be studied for possible revisions to the specifications in line with permissible welding repairs to castings made in other compositions. He also suggests the specifications should state size and nature of defects which may be permitted for welding repair, areas requiring customer approval prior to repairs and subsequent heat treatment. In view of technical improvements, your committee and the AAR research staff will review the current specifications to see if they can be relaxed.

A study is being made on the assignment regarding explosive hardening of manganese frogs and it is being progressed.

The assignment covering necessary information required to determine the selection of desired type of railroad crossing needed for a specific location is being progressed, having in mind the possible revision of AREA Plan 700–55.

AREA Plan 791–59, Table of Practical Gages and Flangeways for Curved Track, is being reviewed with the thought of simplifying the data shown on this plan and other related plans.

Our study of bridge expansion joints is being progressed at the AAR Research Center.

AREA Plans 791–59, 792A–59 and 792B–59 are to be combined, and the steam series will be deleted with regard to gages and flangeways. Also it has been suggested that information be included for the newer series of diesel locomotives.

Report on Assignment 6

Hold-Down Fastenings

E. C. Honath (chairman, subcommittee), L. R. Hall, C. N. King, O. F. Magnus, C. A. Peebles, L. A. Pelton, B. Post, R. N. Schmidt, V. M. Schwing, C. W. Wagner, M. J. Zeeman.

CONCRETE TIES

Your committee is collaborating with Committee 3 in developing specifications for the design, materials, construction and inspection of prestressed concrete ties, including the necessary fastenings. At present, we have under consideration and are in the process of developing information and recommendations as to the requirements for fastenings, rail anchorage, and tie spacing as related to the track structure.

Report on Assignment 7

Effects of Lubrication in Preventing Frozen Joints and Retarding Corrosion of Rail and Fastenings

Ross P. Roden (chairman, subcommittee), L. A. Pelton, C. E. Peterson, V. M. Schwing, V. C. Hankins, A. C. Trimble.

Your committee submits the following progress report as information.

RAIL CORROSION INVESTIGATION

Great Northern Railway, Seattle, Wash.

In September 1958, 107 rails in the extremely wet King Street Tunnel of the Great Northern Railway in Seattle, Wash., were sand-blasted clean and painted with preservative paints. Some of these preservatives were Insulmastic 4010, Metal Coat A, Enamelex, No. 45 Neoprene, Minnesota Mining coating No. 10 and coating No. 11 and No. 41-B "Allgood." In December 1960, additional rails were treated with "Neoweld" M-720-C coating. At the time the latter rails were placed in the tunnel (1960), it was noted that the Allgood coating, applied only two years previously, was failing and not performing as expected. This was true of the other coatings also to a lesser extent.

An inspection was again made of these rails in the tunnel in 1967 and, from all indications, none of the coatings tested has given satisfactory results. Even in a few of the dry areas of the tunnel, corrosion of the rail was prevalent. In some instances in the wet areas, the coatings were completely gone.

It appears that any further inspection of these test coatings would not be warranted.

RAIL JOINT LUBRICATION INVESTIGATION

Richmond, Fredericksburg & Potomac Railroad, Franconia, Va.

In January 1957, a field test was originated on the RF&P for the evaluation of various products and methods of application for rail joint lubrication and corrosion prevention. A one-mile stretch of track with new rail at Franconia, Va., was picked for the test and each rail joint was treated with various lubricants and preservatives as follows:

66 joints—6-inch plastic packing, receiving end of joint; no other lubrication.

66 joints—Plastic packing solid except for 3 inches at rail ends.

66 joints—Brush coat Conoco Anti-Rust compound, Texaco H end plugs, receiving end only.

Texaco 904—Brush coat, heavy.

Texaco 1978—Brush coat, heavy.

No-Ox-Id "GG"—Brush coat, heavy.

Certain representative joints were inspected in 1959, two years after application, and all materials were found to be doing very well.

The same joints were again inspected in 1967, 10 years after application; this inspection revealed the following conditions:

Six inch plastic packing—receiving end of joint; no other lubrication: Most of the end packings were gone, but where they were still in place, good protection to the end bolts was afforded. No serious corrosion was found on most bars and rail, but some joints had considerable rust under the bars, mainly on the field side. The bolts were in good condition.

Plastic packing solid except for 3 inches at rail ends: The bolts were in good condition. No bleeding was found on top of the bars but there was some on the bottom bearing surface. Slight corrosion was observed on receiving end of some bars which did not reach the first bolt. There was a good protective coat remaining on both rail and bars.

Brush coat Conoco anti-rust compound, Texaco H end plugs, receiving end only: Some plugs were deteriorated or gone. In most joints, the bolts were in good condition and the bearing surfaces were generally well lubricated. There was some corrosion on the top of the rail base for about 6 inches from the receiving end of the bars. Also corrosion to a limited extent was observed on the web of the bars and rail.

Texaco 904: The bolts were in good condition. There was quite a bit of corrosion for 8 to 10 inches on the receiving ends of bars, field side, and also on the base and the under head of the rail. A smaller amount of corrosion was observed on the gage-side bars and rail.

Texaco 1978: The bolts were in good condition, and there was only 3 to 4 inches of corrosion on the receiving ends of bars and rail, both field and gage sides. The rest of the bars and rail had some remaining protective coating.

No-Ox-Id "GG": The bolts were in good condition, but more corrosion was found at the receiving ends of the bars, both top and bottom and under head of rail. Protective cover on bearing surfaces of bars and rail was poor.

It appears that the solid packing of joint bars is affording the best and longest lasting lubrication and corrosion protective qualities.

BRINE CORROSION PROTECTION INVESTIGATION

Chicago & North Western Railway, Low Moor, Iowa

During 1959 and 1960 the Chicago & North Western Railway established a five-mile service test of brine corrosion protection in its eastward main track near Low Moor, Iowa, which had been relaid with 78-ft butt-welded 115 RE rail in 1957. Four of the five miles were sprayed out-of-face. Mile 11 is the control section with no protection until July 18, 1962, when special compounds or paints were applied to some of the welds after flame cleaning and wire brushing.

Data on the five test sections are given below:

Mile	*Metal Preservative*	*Date Applied*	**Years of Brine Corrosion*	*Years of Service*
11	None	—	10	—
12	No-Ox-Id 100	Sept. 1959 except part of south rail		
13	Texaco 45	Sept. 1959	—	8
14	Texaco RCX-236	Aug. 1960	—	7
15	Texaco 55	Sept. 1960	—	7

* Prior to first spraying.

The inspection of the rail and fastenings made in 1961 developed that the most serious corrosion and rust scales were in the weld areas. Later it was decided to give a few welds some special coatings after cleaning the rail. The following table shows the application of the metal preservatives made in July 1962.

List of Butt Weld Areas, Flame Cleaned and Wire Brushed to Apply a Brush Coat of Preservatives Listed

Mile	*Preservative*	*Number of Welds*
*11	Galvanox Type I	9
	Galvanox Type II	6
	Lead Suboxide Paint No. 508	10
	Coal Tar Epoxy	20
		—
		45
12	No-Ox-Id 100 recoated with No Ox-Id-AZ	20
12	Texaco 45	0
14	RCX-236	0
15	Texaco 55	20
		—
		40
	Total	85

* Mile 11 is the control section without protection except at the 45 welds noted above.

A 2-ft length of rail was given a brush coat of the preservative at the welds shown above, except that in Mile 12, No-Ox-Id-AZ (containing aluminum pigment) was used to replace the No-Ox-Id 100, originally applied in 1959.

These test miles were again inspected in 1967 by your committee and conditions of the rail and fastenings and the preservatives were found to be as follows:

Mile 11, the control mile, which had not been treated with any protective paints or coatings, showed heavy corrosion at the welds, but very little on the rail joints and track fastenings.

Mile 12, treated with No-Ox-Id 100 in 1959, had lost all effective protection derived from the 1959 application and was considered, for all practical purposes, no better than the control mile.

Mile 13, treated with Texaco 45 in 1959, also had lost most of the protection from the original coating and was practically in the same condition as Miles 11 and 12.

Mile 14, treated with Texaco RCX-236 in 1960, also showed corrosion on most of the welds; however, the coating on approximately one-third of the welds was still good.

Mile 15, treated with Texaco 55 in 1960, while showing corrosion at many of the welds, still had some coating left on a few of the welds.

In addition to the service tests from Mile Posts 10 to 15, the subcommittee inspected another location in the same track a few miles distant where the C&NW had sprayed Texaco 55 each year. The committee found that the welds there were adequately protected.

It is the conclusion of the subcommittee that no coating provided corrosion protection for the entire period of seven or eight years during which the Low Moor test has been in progress and recommends that the coatings be applied at least every three years.

The Low Moor test location has served its purpose and the committee has so advised the C&NW Railway.

C&NW Railway, Elmhurst, Ill.

To further the study of preservatives and protective coatings, the C&NW Railway has graciously set up a new test location in Elmhurst, Ill., where new welded 115-lb rail has been laid recently. Here several new products will be applied to the web and base of the rail, as was done at the Low Moor location. These will be evaluated for their effectiveness against brine corrosion.

ACKNOWLEDGMENTS

Your committee and the AAR Research Center is grateful and indebted to the Great Northern Railway, the Richmond, Fredericksburg & Potomac Railroad and the Chicago & North Western Railway for their past and continuing cooperation and assistance in the conduct of these investigations.

Report on Assignment 9

Special Requirements of Track Construction and Maintenance Due to Operation of Equipment with High Center of Gravity and/or Hydraulically Cushioned Underframes

L. W. GREEN (chairman, subcommittee), C. R. ALBERTS, W. R. BJORKLAND, E. H. BLANK, J. R. BOWMAN, L. E. BRAULT, K. L. CLARK, J. P. COLLINS, C. D. DAVIS, A. D. DEMOSS, J. J. EASH, W. E. GRIFFITHS, A. B. HILLMAN, JR., B. J. JOHNSON, R. A. KELSO, C. N. KING, L. T. KLAUDER, R. E. KUSTON, R. F. LAWSON, J. G. MARTIN, T. D. MASON, P. R. MATTHEWS, G. H. MAXWELL, T. C. NETHERTON, G. A. PAYNE, B. E. PEARSON, C. A. PEEBLES, L. A. PELTON, C. E. PETERSON, J. A. POLLARD, L. E. PORTER, B. POST, J. M. SALMON, JR., A. J. SCHAVET, V. M. SCHWING, R. W. TIPPER, W. J. WANAMAKER.

The following report is presented as information only.

As has been covered by Manual material presented for adoption in the Manual Recommendation Supplement to the December 1967 Bulletin, there are certain conditions where the extreme height of the center of gravity of a freight car requires that its safe operating speed be lower than that generally accepted for passenger trains, i.e., 3 inches unbalanced. This is in order to eliminate the possibility of overturning on curves where the resultant force will fall out of the middle third of the track.

There is also a problem with the operation of cars with an extremely high center of gravity at slow speeds or which come to a stop on curves with maximum superelevation. It may be assumed that the distance center to center of bearing of rails at standard gauge is 60 inches so that with curves carrying 6-inch superelevation, the inclination of the track is 1:10. A car with height of the center of gravity at 100 inches or more standing on a curve with 6 inch superelevation, discounting lateral play in trucks or truck center and action of the springs, will have the resultant force fall just 10 inches from the center of the tie toward the low side (thus at the edge of the middle third, i.e., 20 inches). When a train handling such cars starts to move, there is a dynamic action on the couplers and trucks which has a tendency to force the car's center of gravity toward the inside of the curve and the resultant force to a point outside the middle third of the tie toward the low rail.

It would appear that railroads regularly operating cars with height of center of gravity in excess of 100 inches should investigate the feasibility of reducing its maximum superelevation to 5 inches or even 4 inches.

Report on Assignment 10

Modern Methods of Heat Treating Carbon Steel Trackwork and Repairing Such Trackwork by Welding

S. H. Poore (chairman, subcommittee), W. R. Bjorklund, J. R. Bowman, L. E. Brault, J. E. Campbell, J. P. Collins, A. D. De Moss, J. J. Eash, W. E. Griffiths, L. R. Hall, Louis T. Klauder, R. E. Kuston, G. H. Maxwell, B. E. Pearson, G. H. Perkins, C. E. Peterson, Bernard Post, V. M. Schwing, R. W. Tipper, C. W. Wagner, I. V. Wiley, G. G. Knupp, O. F. Magnus, J. F. Smith, K. H. von Kampen.

Your committee submits the following report on the above subject, which subject was originally assigned in 1952. Progress reports have been published in the Proceedings Vols. 54 through 68, and in discussions in Convention Proceedings.

General

A program was developed to provide for investigation of heat-treated rail and flame-hardened rail in crossing frogs by means of service installations. A contract was made with the Chicago, Milwaukee, St. Paul & Pacific Railroad for installation of three test panels of crossing intersections at Mannheim, Ill., each of the three test panels to consist of eight simulated crossing intersections—three of carbon-steel rail, heat treated by various methods; three of flame-hardened carbon-steel rail; one carbon-steel panel of control-cooled rail (as rolled) and one panel of used chrome-vanadium rail. The studies of welding techniques were carried out at the AAR Research Center and the University of Illinois.

The investigation was carried out by the AAR as a function of its Research Department, W. M. Keller, vice president. The service installation on the Milwaukee Road and laboratory studies were under the general direction of G. M. Magee, director of engineering research, Engineering Research Division.

A detailed description of the work done by the AAR appears in AAR Research Department report ER-51 dated November 1964 and distributed to Chief Engineers of Member Roads April 26, 1965.

Fabrication of Test Units

Six manufacturers, working as a group and collaborating with the subcommittee, furnished three 39-ft panels of eight units of flangeway intersections. Each panel was of the construction shown in Fig. 1. Each manufacturer obtained two 132 RE rails from the same heat which had carbon content above the median of the specified carbon range. Each prepared three sets of running and easer rails without charge, and the Pettibone Mulliken Corporation prepared the design, furnished the balance of the material and fabricated the three panels at actual cost.

Flame hardening was done respectively by: Pettibone Mulliken Corporation; Trackwork Division, Taylor–Wharton Iron and Steel Co.; and the Ramapo Ajax Division of Abex. The Pettibone Mulliken and Taylor–Wharton methods of flame-hardening were similar in that each used dehydrated compressed air as the quenching medium. Ramapo's method utilized ambient air as a quench, followed by a water bath about 10 in behind the oxyacetylene flame after the rail had dropped below the critical temperature. Heat treatment was furnished respectively by:

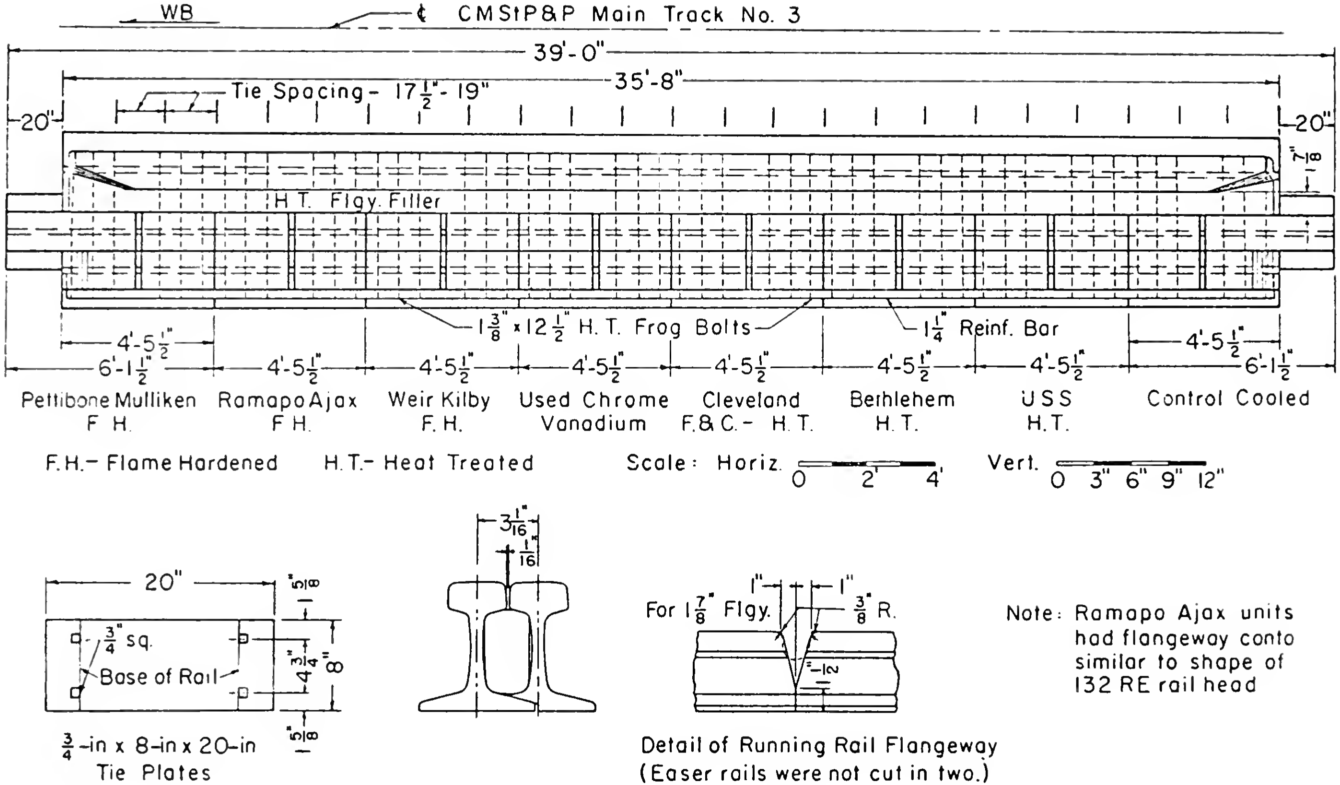

Fig. 1. Plan of One Panel of Eight Units of Simulated 132 RE Bolted Rail Crossing Flangeway Intersections at Mannheim, Illinois.

Bethlehem Steel Corporation; Cleveland Frog and Crossing Company and United States Steel Corporation, Johnstown Works. USS used in its heat-treating process a water quench and the other two frog manufacturers used oil as the quenching medium. The control-cooled rail units were also made of rails of the same heat. The low alloy chrome-vanadium was included to determine its suitability for bolted rail crossing construction and to investigate repair by welding. The Norfolk & Western Railway furnished one of its 132 RE C-V rails which had carried 90 million gross tons of traffic in the outer rail of a 6-deg curve. Chrome-vanadium rail is a self-hardening rail and has a Brinell hardness of about 350 in the "as rolled" condition. The head wear on the chrome-vanadium rail used was negligible.

Installation of Test Panels

The Milwaukee agreed to install the three 39-ft test panels in its main track No. 3 at Mannheim. Track No. 3 carried heavy slow-speed freight traffic enroute to the new hump yard at Bensenville. All trains were diesel powered and there was no passenger traffic on this track. The grade of the track was about level. New or good, used 7-in by 9-in by 9-ft creosoted oak ties were used, all the extra length being placed under the south rail in which the test units were placed. The three test panels were separated by one 39-ft rail length and eight rail lengths of the north rail were also relaid with new 132 RE rail and six hole joint bars.

The old ballast was removed and replaced with Janesville processed gravel. The 1⅜-in frog bolts were tightened with a power track wrench.

Construction was started on April 12, 1954, and completed April 15, 1954.

Service Test Measurements

Initial or base readings for rail batter and wear and for hardness of the running surface of the steel in the 24 units were taken in the Pettibone Mulliken shop prior to installation in track. These readings were taken on the center line of the rail with batter readings being obtained ¾ in from the nearest face of each flangeway. These hardness readings are shown in Table 1.

Materials in Test

As shown on Fig. 1, nine flame-hardened units, nine fully heat-treated units, one of used chrome-vanadium rail, and one of open hearth control-cooled rail were constructed. All of the rails used were from the same heat, except the C-V rail. Further descriptive material appears in Vol. 56, pages 878 to 888.

First Traffic Period

After the installation, frequent examinations were made, and flowed metal removed by grinding as appeared necessary. This procedure was followed until September 1957, at which time the units had carried 91 million tons of traffic and the receiving corners of the intersections had developed end batter varying from 0.13 in. on the non-treated carbon steel units to 0.05 in. on some of the fully heat-treated units as shown in Table 1, Column "A".

It will be noted that the fully heat-treated units, and C-V unit showed the least batter, and, as might be expected, the carbon steel units the greatest. The flame-hardened units showed up better than the carbon steel units, although two flame-hardened units showed more batter than the other seven.

The general performance of the heat-treated, flame-hardened and C-V units seems to indicate that the harder material defers the onset of batter, or saying it differently, the hardened rails are superior to the as-rolled rail prior to repair. The

BATTER AND HARDNESS READINGS TAKEN AT RECIEVING ENDS ON TOP OF RUNNING RAILS ON SIMULATED CROSSINGS ON THE MILWAUKEE AT MANNHEIM, ILLINOIS.

TABLE 1

Panel	Unit No.	Description of Unit	Welding Procedure	"A" Batter Before Welding Sept 1957	"B" Hardness at Time of Installation Apr. 1954	"C" Rate of Batter per 100 Million Tons of Traffic on Original Steel	"D" BN Hardness After 91 Million Tons Traffic & Before Welding Sept 1957	"E" BN Hardness Immediately After Welding Sept 1957	"F" Batter at Time of Removal from Track Nov. 1963	"G" Rate of Batter per 100 Million Tons of Traffic on Welded Steel	"H" BN Hardness at End of Test Nov 1963
FLAME HARDENED RAIL											
WEST	W-1	PETTIBONE-	4-E	0.07	307	.0769	375	302	0.11	.0529	338
CENTER	C-1	MULLIKEN	3-E	0.09	315	.0989	364	302	0.11	.0529	338
EAST	E-1	CORPORATION	1-G	0.09	311	.0989	364	302	0.18	.0865	300
WEST	W-2	RAMAPO AJAX DIV	3-E	0.06	359	.0660	399	327	0.14	.0673	332
CENTER	C-2	OF ABEX	2-G	0.07	368	.0769	402	347	0.15	.0721	332
EAST	E-2		1-G	0.08	366	.0879	408	327	0.16	.0769	293
WEST	W-3	WEIR	3-E	0.08	302	.0879	351	382	0.14	.0673	321
CENTER	C-3	KILBY	1-E	0.11	321	.1210	347	359	0.12	.0579	361
EAST	E 3	CORPORATION	1-G	0.11	290	.1210	366	317	0.24	1153	313
HEAT TREATED RAIL											
WEST	W-5	CLEVELAND FROG	3-E	0.05	340	.0550	390	351	0.13	.0625	338
CENTER	C-5	AND CROSSING	1-E	0.05	332	.0550	390	293	0.12	.0577	302
EAST	E-5	COMPANY	2-G	0.06	337	.0660	390	351	0.13	.0625	321
WEST	W-6	BETHLEHEM	4-E	0.05	327	.0550	374	340	0.13	.0625	338
CENTER	C-6	STEEL	3-E	0.06	340	.0660	387	340	0.13	.0625	321
EAST	E-6	COMPANY	1-G	0.06	342	.0660	402	262	0.17	.0817	324
WEST	W-7	UNITED STATES	4-E	0.05	344	.0550	387	332	0.13	.0625	351
CENTER	C-7	STEEL	3-E	0.06	327	.0660	385	359	0.13	.0625	340
EAST	E-7	CORPORATION	1-G	0.06	311	.0660	387	321	0.13	.0625	321
OTHER PAILS											
WEST	W-4	USED CHROME	7-AE	0.05	366	.0550	359	438	0.12	.0577	351
CENTER	C-4	VANADIUM	2-AG	0.06	359	.0660	368	266	0.17	.0817	277
EAST	E-4	RAIL	1-AG	0.06	366	.0660	359	286	0.14	.0673	317
WEST	W-8	CC BLUE END RAIL AS ROLLED	6-E	0.11	249	.1210	302	266	0.21	.1010	364
CENTER	C-8	(C 078, MN 082, PH 0.11,	2-G	0.13	254	.1430	302	302	0.20	.0962	352
EAST	E-8	SUL 0.36, SIL 018)	1-G	0.13	245	.1430	298	293	0.11	.0529	298

NOTE – THE UNITS WERE INSTALLED APRIL 13, 1954 AND HAD CARRIED 91 MILLION GROSS TONS OF TRAFFIC PRIOR TO WELDING IN SEPTEMBER, 1957. TRAFFIC AFTER WELDING UNTIL REMOVED FROM TRACK IN NOVEMBER, 1963 WAS 208 MILLION GROSS TONS A TOTAL OF 299 MILLION GROSS TONS TOTAL FROM DATE OF INSTALLATION

COLUMNS "C" AND "G" = (BATTER IN HUNDREDTHS / TONNAGE IN MILLIONS) × 100 = RATE OF BATTER

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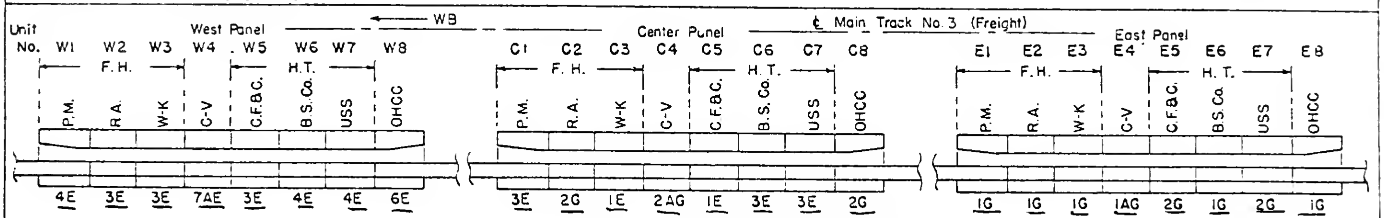
TABLE 2 WELDING PROCEDURES FOR REPAIRING SIMULATED CROSSING UNITS ON THE MILWAUKEE ROAD AT MANNHEIM, ILLINOIS

(1). Pregrinding for all welding. Remove defective metal by grinding. (2). Finishing. Peen all gas welds while hot and finish by grinding after post heating if required when metal is cold. In electric welding lightly peen beads as deposited and finish by grinding after welding or post heating when the metal is cool. Care should be exercised to avoid burning the steel by grinding.



Location Plan of Test Units Showing Welding Procedures

Welding Procedure	Preheating	Description of Welding Rods	Post Treatment
1G (a)	None	AIRCO RR rod, bare (Use 5%–10% carburizing flame)	None
1AG	do	do	Post-heat to 1000° F for 20 minutes
2G (a)	None	Oxweld M.W. rod, bare	None
2AG	do	do	Post-heat to 1000° F for 20 minutes
1E	Preheat to 350° F for 10 minutes	AIRCO No. 361 coated electrode	None
3E	Preheat to 500° F in temperate weather and to 550° F in cold weather	Teleweld Cro-Moly-Mang electrode Type 16 coating (GE S-32)	Post-heat to 800° F. Air cool in temperate weather. Blanket in cold or cool windy weather
4E	Preheat to between 300°F and 400°F	A. O. Smith Diamond-Weld A electrode (B.S. Co.)	Post-heat to 700°-800°F as soon as welding is completed
6E	Preheat to 400° F	McKay E-973 coated electrode (Milw. Rd.)	None
7AE	Preheat to 500°-600° F	National Cyl. Gas Co. No. 170 RR rod with International Rail Weld Corp. coating	Post-heat with torch 20 minutes to 1000° F

Notes: P. M. = Pettibone Mulliken Corp. R.A. = Ramapo Ajax Division. W-K = Trackwork Division, Taylor-Wharton Iron & Steel Corp. C-V = Chrome-Vanadium alloy steel. C. F. & C. = Cleveland Frog & Crossing Co. B. S. Co. = Bethlehem Steel Company. USS = United States Steel Corp. OHCC = Open hearth control cooled rail, as rolled. F.H. = Flame hardened rail. H.T. = Heat treated rail.
All rail temperatures are to be checked with Tempilstiks and recorded.
(a). When gas welding heat treated and flame hardened units, avoid overheating the base metal and apply the weld metal in small patches on the tread corners.

possibility of using C-V rail in this type of track construction is suggested if it can be made available. The higher cost of C-V rail may be less than the cost of fully heat-treated rail. It is interesting to note that all units except the C-V rail increased in hardness with the passage of the first 91 million tons of traffic. The C-V rail had its work hardening before it became a part of this test.

Welding Techniques Selected

To determine the most promising welding techniques for the eight kinds of test units, an extensive plan for experimental welding was developed and carried through. This is reported in detail in Report No. ER-51 (1964) and AREA Proceedings Vols. 56 (page 878), 57 (page 768), 58 (page 903), and 59 (page 1005). Table 2 summarizes the welding methods adopted and provides a key to the column marked "Welding Procedure" in Table 1.

The deposited weld metal, before traffic, was not as hard as the work-hardened steel it covered, except in the case of two of the flame-hardened units, vis., W-3 and C-3 and unit W-4 in the C-V group. It may be significant that all three of these exceptions were electric welds.

Final Phase

After restoration of the battered ends in September 1957, the panels were allowed to remain in service until November 1963, at which time they had carried a total of 299 million tons of traffic, 91 million before repair by welding, and 208 million after welding. At the time of removal from track, batter and hardness readings were taken. These are listed in columns "F" and "H", respectively, in Table 1.

Batter

The batter readings were understandably greater in this phase of the test (208 million tons, compared to 91 million tons); however if we reduce both the sets of figures to inches of batter per 100 million tons of traffic we get a better picture—compare columns "C" and "G" in Table 1.

Flame-Hardened Units

In the three groups of flame-hardened units, the batter rate decreased, with one exception. This unit (W-2) had the lowest batter rate in the group to start. Neglecting this one exception, the electric welds had a lower batter rate after repair by welding than the gas welds on flame-hardened carbon steel trackwork.

Fully Heat-Treated Units

The three groups of fully heat-treated units showed very little change in rate of batter; four of the electric welds showed a slight increase in batter rate and two a decline. Two of the three gas welds in this group showed slight decreases in rate, but the third one, E-6, showed a marked increase in batter rate.

Chrome-Vanadium Units

The batter on the three C-V units after welding (one electric procedure and two gas), made no pattern except it should be noted that the batter rate increased after welding in all three units. One of the gas welded units showed a marked increase in rate.

CC Blue-End Rail (As Rolled)

The non-heat treated "as rolled" carbon steel rail units performed as might be expected. They had the highest batter rate before welding. Welding reduced the batter rate. The two gas welds seemed to do better than the electric weld.

Final Hardness

From the figures in column "H", Table 1, there seems to be no consistent pattern of work hardening after repair by welding. Some of the flame-hardened units, electrically welded, showed work hardening, others did not. None of the gas welded units showed evidence of work hardening. The fully heat-treated units showed the same spotty work-hardening pattern. The chrome-vanadium panels showed work hardening after welding—regardless of the weld procedure. The "as rolled" carbon steel units showed a hardening after welding, although one gas welded unit showed only very slight hardening.

CONCLUSIONS

In drawing conclusions from such a test as described above, it should be kept in mind that it was of limited scope, even though it extended over a nine-year period in track. For example there were three sets of flame-hardened units, nine in all, each set being flame-hardened by a different process. These nine units were repaired by five different welding techniques, two gas, and three electric. Substantially the same discussion applies to the fully flame-hardened units. It is possible that some roads over the past 10 or 12 years have, on their own lines, explored and developed materials and techniques entirely different from those in this test. Therefore the conclusions listed below do not constitute a complete map of future performance, but we believe they point the way to better trackwork materials and maintenance in the future.

1. Both flame-hardened and fully heat-treated materials resist batter and ordinary wear better than "as rolled" carbon steel, the fully heat-treated material better than the flame-hardened. The need for repair by welding of the flame-hardened and fully heat-treated material is deferred as compared to "as rolled" carbon steel, although grinding to remove metal flow should be done.
2. Electric welds on flame-hardened material give a better repair job than gas welds.
3. Both electric and gas welds on fully heat-treated material give comparable results if proper welding rod is used.
4. Gas welds on "as rolled" carbon steel give better results than electric welds.
5. The results of this test suggest the possibility of extending the use of chrome-vanadium steel to the manufacture of trackwork.
6. Repair by welding of flame-hardened, and fully heat-treated frog, switch and crossing intersections will materially extend the service life of this type of track material.

Acknowledgment

The Association is grateful to the Milwaukee Road, the Burlington Lines and the suppliers of the test units for their fine cooperation and assistance in conducting this investigation. The valuable aid in the matter of developing and carrying out the field welds by the following companies is acknowledged with thanks: Milwaukee Road, Burlington Lines, Air Reduction Sales Company, Linde Air Products Company, Teleweld Inc., Bethlehem Steel Corporation and International Rail Weld Corporation.

The investigation was carried out by the AAR as a function of its Research Department, W. M. Keller, vice president. The service installation on the Milwaukee Road and laboratory studies were under the general direction of G. M. Magee, director of engineering research, Engineering Research Division. H. E. Durham, former research engineer track, was in direct charge of the investigation. K. Kannowski, former metallurgical engineer, aided in planning the laboratory welding tests and evaluating the welds and R. E. Cramer, former special research associate professor, University of Illinois, conducted the metallurgical examinations of the welds. Mr. Kannowski and M. J. Wisnowski, metallurgical engineer, made the metallurgical examinations and evaluated the specimens at the completion of the tests. L. R. Lamport, former assistant research engineer track, prepared the report.

References

For progress reports covering this investigation, see AREA Proceedings Vol. 55, page 768, Vol. 56, page 878, Vol. 57, page 768, Vol. 58, page 903, Vol. 59, page 1077, Vol. 60, page 862, Vol. 61, page 971, Vol. 62, page 673, Vol. 63, page 495 and Vol. 64, page 446.

Report of Committee 31—Continuous Welded Rail

°**C. W. Wagner,**
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°**B. J. Johnson,**
Vice Chairman

°**B. J. Gordon,**
Secretary

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E. H. Waring
C. E. Weller
J. R. Zadra

Committee

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 31.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Fabrication.

Part 1—AAR Investigation of Service and Detected Butt Welded Rail Joint Failures, presented as information .... page 574

Part 2—Results of Rolling-Load and Slow-Bend Tests of Butt Welded Rail Joints, presented as information .... page 589

Part 3—Butt Weld Failure Statistics, presented as information ...... page 598

2. Laying.

Statistics—Track Miles of CWR Laid by Years, presented as information .... page 599

3. Fastenings.

Anchorage of Continuous Welded Rail, progress report presented as information .... page 600

4. Maintenance.

The current assignment, Transposing Continuous Welded Rail, requires further study. A report will be presented next year.

5. Layout of fixed and portable welding plants.
   A report on this assignment will be presented next year.

6. Welding second-hand rail.
   Inspection and Classification of Second-hand Rail for Welding, progress report presented as information .... page 617

The Committee on Continuous Welded Rail,
C. W. Wagner, *Chairman.*

AREA Bulletin 612, February 1968.

Report on Assignment 1

Fabrication

A. H. Galbraith (chairman, subcommittee), S. H. Barlow, R. M. Brown, J. E. Campbell, W. J. Cruse, A. R. DeRosa, B. J. Gordon, C. W. Grater, B. J. Johnson, K. H. Kannowski, G. G. Knupp, H. F. Longhelt, L. H. Martin, A. S. McRae, C. E. Morgan, S. H. Poore, B. R. Prusak, C. W. Wagner, J. R. Zadra.

Your committee has been investigating "Non-destructive Testing of Welds" and it is expected that a report will be presented next year.

The current report on Assignment 1 is presented in three parts. Part 1 is a report on an AAR investigation of service and detected butt welded rail joint failures. Part 2 presents the results of rolling-load and slow-bend tests of butt welded rail joints carried out at the AAR Research Center. Part 3 presents statistics on butt weld failures.

PART 1

INVESTIGATION OF SERVICE AND DETECTED BUTT WELDED RAIL JOINT FAILURES

In the period between October 1, 1966, and October 1, 1967, there were seven service and no detected failures in butt welded rail joints investigated by the metallurgical laboratory of the Association of American Railroads Research Center. A summary of these service failures can be found in Table 1. On completion of these metallurgical investigations a report was sent to the railroads submitting the failure and to the American Iron and Steel Institute's Technical Committee on Railroad Materials to be forwarded to the manufacturer producing the rail.

Investigation 136–22 was conducted at the request of the Great Northern Railway and involved an electric flash butt welded joint that failed in service. The rails used in the fabrication of this joint were 112-lb RE sections rolled by the United States Steel Corporation's Gary Works in July 1942 bearing identification designations 57378-F-25 and 57378-C-10. These rails were metallurgically examined and found to be of sound steel quality. The fractured faces of this failed joint can be seen in Fig. 1. An entrapment (black area) introduced during the welding process can be noted in the web on the fractured faces. A photomicrograph of a specimen that was cut longitudinal to the rail in a vertical plane through the entrapment can be seen in Fig. 2. It can be noted that this entrapment (between the fractured face and ferrite band) is porous. This failure could be attributed to an entrapment introduced during the welding process.

Investigation 136-25 was conducted at the request of the Bessemer & Lake Erie Railroad and involved a rail, part of a continuous welded string, that failed in service. This rail was identified as a 140-lb PS section rolled in 1959. The fractured faces of this failed rail showing a discolored area in the base can be seen in Fig. 3. A transverse section was cut from the base adjacent to the fractured face and etched with a 10 percent nital solution. A photograph of the etched section showing several electrode burns in the base can be seen in Fig. 4. This failure can be attributed to these electrode burns which were introduced during the welding process.

Investigation 136-27A, B and C was conducted at the request of the Erie Lackawanna Railroad and involved three electric flash butt welded joints that failed in service. The rails used in the fabrication of these three joints were 132-lb RE sections rolled by the Bethlehem Steel Corporation's Lackawanna Mill in August 1965. The rails of each joint were identified as follows:

Sample A—400065-A- 1 and 390078-A-34
Sample B—390078-A-33 and 390078-A-40
Sample C—390078-A-30 and 400065-A-15

A side view of these failed joints can be seen in Figs. 5, 9 and 13. All these fractures started at the weld and progressed in a horizontal plane along the neutral axis. The fractures in specimen A and B veered toward the head and base, resulting in a complete separation. Photographs showing the fractured faces of the three specimens can be found in Figs. 6, 10 and 14. It can be noted that a line extends through the center of the web, one rail of each joint, which indicates that a pipe is present in that rail. Transverse sections were taken from each side of these joints and macro-etched in a hot 50 percent aqueous solution of hydrochloric acid to determine the quality of the steel. Photographs showing the macro-etched transverse sections can be found in Figs. 7, 8, 11, 12, 15 and 16. It can be noted that one rail from each joint has a pipe and heavy segregation pattern present. These electric flash butt weld failures can be attributed to this pipe and heavy segregation.

Investigation 136–31 was conducted at the request of the Seaboard Air Line Railroad (now part of the Seaboard Coast Line Railroad) and involved an Orgotherm thermite welded rail joint that failed in service. The rails used in the fabrication of this joint were 115-lb RE sections rolled by the United States Steel Corporation's T.C.&I. Mill in June 1966 bearing identification designations CH30B455-A and CH60B202-C. The fractured faces of this failed thermite weld is shown in Fig. 17. It can be noted that this failure originated in the fillet between the web and base as indicated by the presence of a fatigue ring development. A specimen was taken from this fatigue ring development for a microscopic examination. A photomicrograph showing a layer of martensite at the origin of this failure can be seen in Fig. 18. This failure could be attributed to the presence of a martensite formation that resulted from a heavy grinding of the thermite weld collar after the weld metal had cooled.

Investigation 136–34 was conducted at the request of the Missouri Pacific Railroad and involved an electric flash butt welded joint that failed in service. The rails used in the fabrication of this joint were 136-lb RE sections rolled by the

United States Steel Corporation's T.C.&I. Mill in 1967 bearing identification designations 28CO92-A-9 and 28CO92-A-30. A side view of this failed rail joint can be found in Fig. 19. The failure started at the weld and progressed in a horizontal plane along the neutral axis, then veered toward the head and base in rail A-30, thereby resulting in a complete separation. The Cadweld bond noted in the side of the rail head was affixed after the failure had occurred. The reason for affixing this bond was to complete the track signal block circuit until the rail could be removed. Transverse sections were taken from each side of this joint and macro-etched in a hot 50 percent aqueous solution of hydrochloric acid to determine the quality of the steel. Photographs showing the macro-etched transverse sections can be found in Figs. 20 and 21. It can be noted that rail section A-30 (Fig. 21) has a heavy segregation pattern. A specimen was taken adjacent to the fracture face and etched with a 3 percent nital solution for a microscopic examination. A photomicrograph showing the microstructure at the weld interface can be found in Fig. 22. It can be noted that a cementite outlining the austenitic grains in the fusion zone is present. To verify the presence of the cementite the specimen was repolished and etched with an alkaline sodium picrate solution which attacks and darkens the cementite in a hypereutectoid steel. A photomicrograph of this specimen showing the cementite at the grain boundries can be found in Fig. 23. A chemical analysis was taken of the segregated area in rail A-30 and it was found to have a carbon content of 0.98 percent, which is above the eutectoid point of steel. During the solidification of steel, any carbon in excess of 0.83 percent (eutectoid carbon content) is rejected into the grain boundries as a carbide. This failure could be attributed to the presence of this cementite, which is a very hard and brittle substance. This condition originated from a carbide segregation that occurred in the top portion of an ingot and was carried over into the A rail.

TABLE I
SERVICE AND DETECTED FAILURES OF BUTT WELDED RAIL JOINTS
OCTOBER 1, 1966 to OCTOBER 1, 1967

Lab Failed Rail No	Source of Failed Rail	Size of Rail	Producer (Mill)	Heat No Rail Letter Ingot No	Date Rolled	Classification of Failure: Defective Weld	Classification of Failure: Rail Quality	Type of Weld
136-22	G. N. R.R.	112 lb RE	U. S. Steel Corp. Gary Works	57378-F-25 57378-C-10	7-1942 7-1942	Service failure-foreign entrapment at weld interface.		Electric flash butt weld.
136-25	B. & L. E.	140 lb PS	Unknown	Unknown	1959	Service failure-electrode burn.		Electric flash butt weld
136-27A	Erie Lack.	132 lb RE	Beth. Steel Corp. Lack. Mill	400065-A-1 390078-A-34	8-1965 8-1965		Service failure due to pipe and heavy segregation.	Electric flash butt weld.
136-27B	Erie Lack.	132 lb RE	Beth. Steel Corp. Lack. Mill	390078-A-33 390078-A-40	8-1965 8-1965		Service failure due to pipe and heavy segregation.	Electric flash butt weld.
136-27C	Erie Lack.	132 lb RE	Beth. Steel Corp. Lack. Mill	390078-A-30 400065-A-15	8-1965 8-1965		Service failure due to pipe and heavy segregation	Electric flash butt weld
136-31	S. A. L. R. R.	115 lb RE	U. S. Steel Corp. T. C. & I. Mill	CH30B155-A CH60B202-C	6-1966 6-1966	Service failure due to formation of martensite as a result of improper grinding practice.		Thermite welded rail joint.
136-34	M. P. R. R.	136 lb RE	U. S. Steel Corp. T. C. & I. Mill	28CO92-A-9 28CO92-A-30	1967 1967		Service failure due to the presence of cementite at weld interface. This condition is related to a carbide segregation found in the top portion of an ingot. This area of high carbon content will appear in the A rail.	Electric flash butt weld.

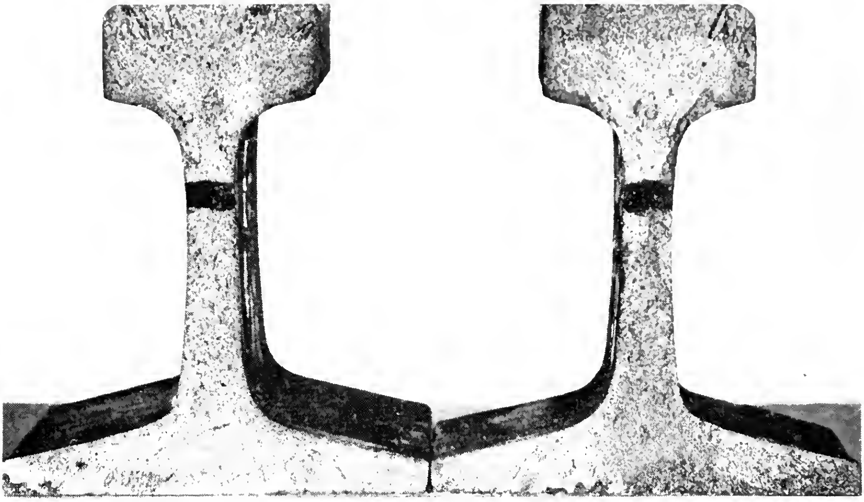


Fig. 1 (Investigation 136–22)—Fractured faces of a failed electric flash butt welded rail joint. The black area in the web is an entrapment that was introduced during the welding process.

Fig. 2 (Investigation 132–22)—Photomicrograph of a specimen that was cut longitudinal to the rail in a vertical plane through the entrapment. It can be noted that this entrapment (between the fractured face and ferrite band) is porous. Etchant—alkaline sodium picrate; magnification 100X.

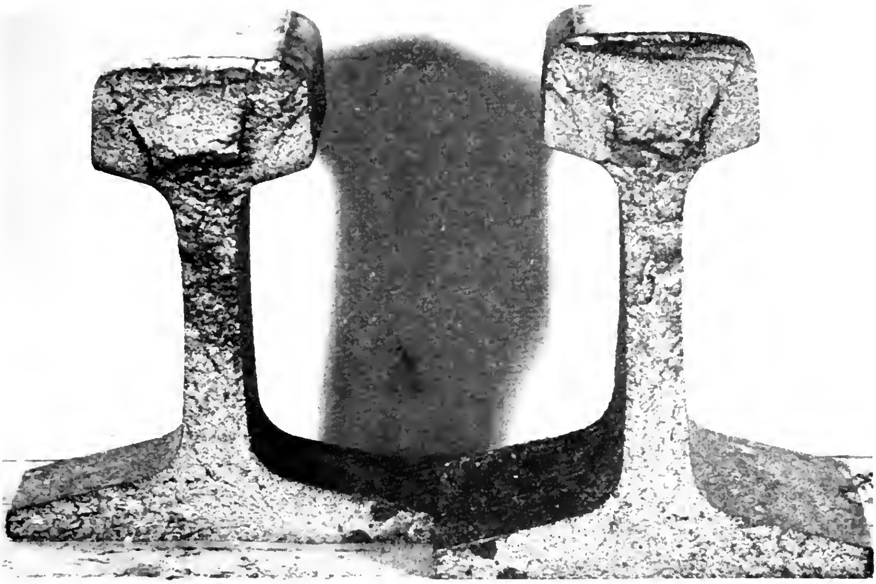


Fig. 3 (Investigation 136–25)—Fractured faces of a failed electric flash butt welded rail joint showing a discolored area in the base which indicates that an electrode burn is present.

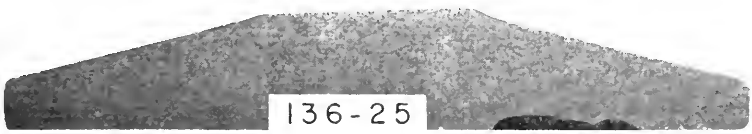


Fig. 4 (Investigation 136–25)—Photograph of a transverse section cut from the base of the rail adjacent to the fractured face. This section etched in a 10 percent nital solution, shows several electrode burns.

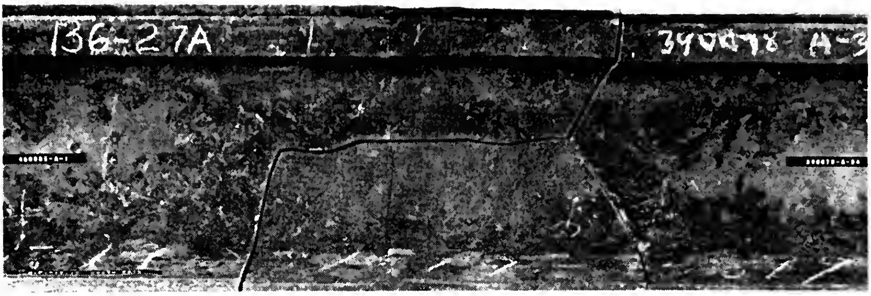


Fig. 5 (Investigation 136–27, Sample A)—Side view of a failed electric flash butt welded rail joint. This fracture started at the weld and progressed in a horizontal plane along the neutral axis, then veered toward the base in the east rail and toward the head and base in the west rail.

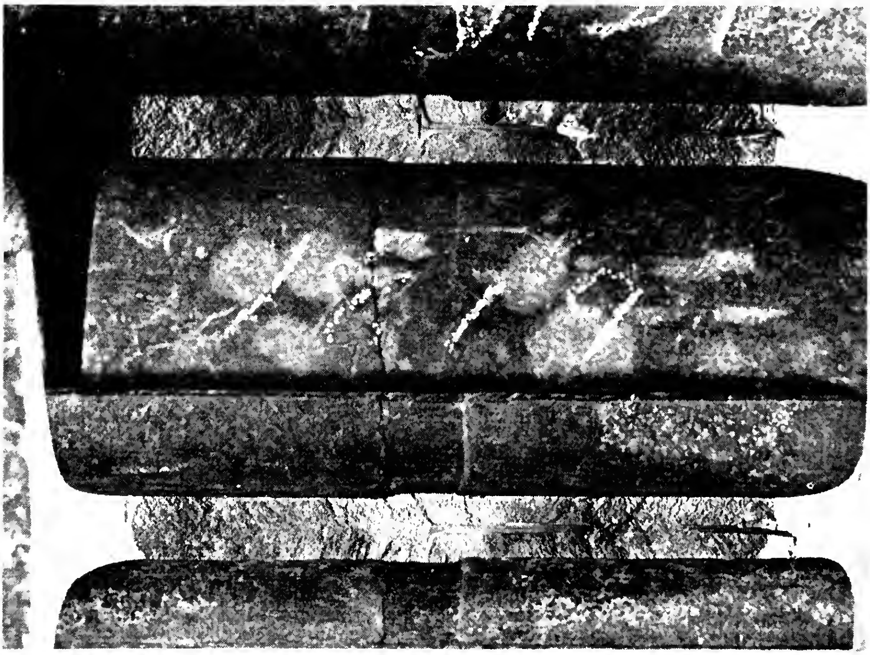


Fig. 6 (Investigation 136–27, Sample A)—Fractured faces of the specimen shown in Fig. 5. The line in the center of the web on the right side of the weld indicates that a pipe is present in this west rail.

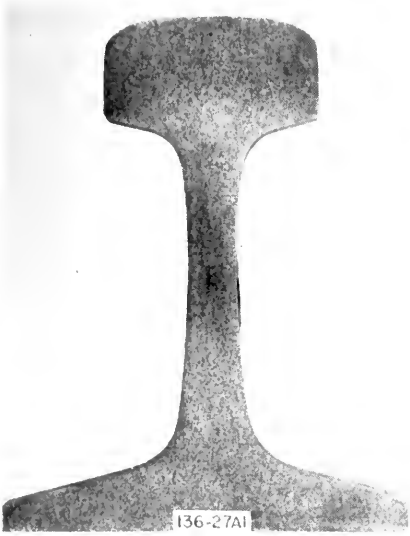


Fig. 7 (east rail)—Sound steel.

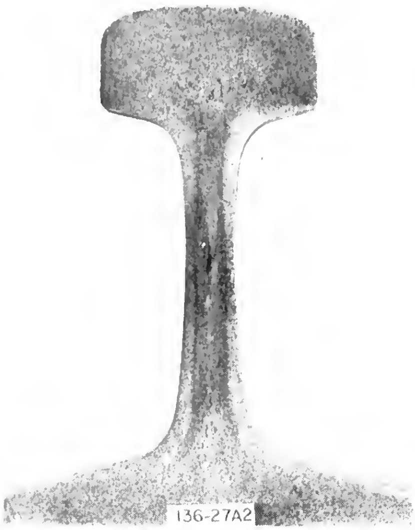


Fig. 8 (west rail)—Pipe and heavy segregation.

Macrophotographs of transverse sections taken from both sides of electric flash butt welded rail joint 136–27A. These specimen were etched in a hot 50 percent aqueous solution of hydrochloric acid.

Fig. 9 (Investigation 136–27, Sample B)—Side view of a failed electric flash butt welded rail joint. This fracture started at the weld and progressed in a horizontal plane along the neutral axis, then veered toward the head in the east rail and towards the head and base in the west rail.

Fig. 10 (Investigation 136–27, Sample B)—Fractured faces of the specimen shown in Fig. 9. The line in the center of the web on the left side of the weld indicates that a pipe is present in the east rail.

Fig. 11 (east rail)—Pipe and heavy segregation.

Fig. 12 (west rail)—Sound steel.

Macrophotographs of transverse sections taken from both sides of electric flash butt welded rail joint 136–27B. These specimens were etched in a hot 50 percent aqueous solution of hydrochloric acid.

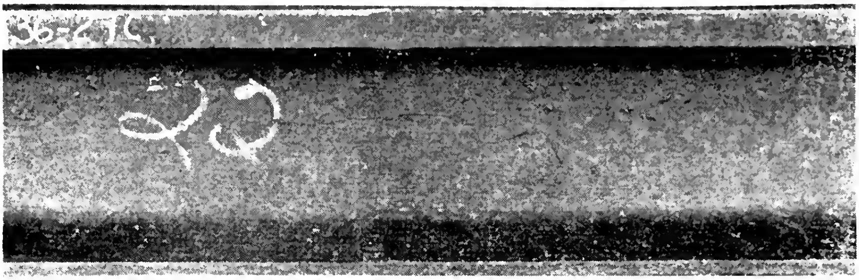


Fig. 13 (Investigation 136–27, Sample C)—Side view of a failed electric flash butt welded rail joint. This fracture started at the weld and progressed in a horizontal plane along the neutral axis. The rail on the left side of the weld is the west rail. The adjoining rail on the right side of this weld is the east rail.

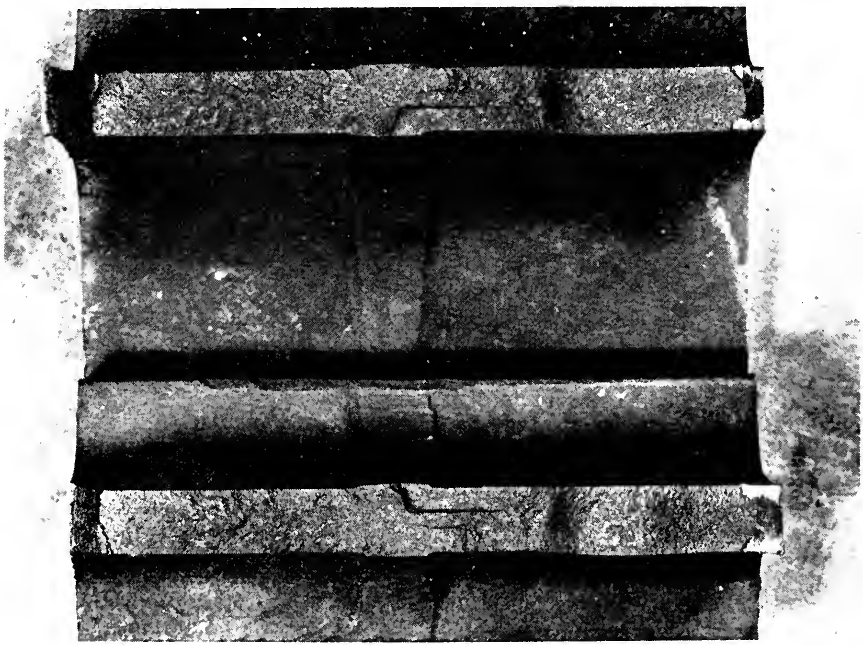


Fig. 14 (Investigation 136–27, Sample C)—Fractured faces of the specimen shown in Fig. 13. The line in the center of the web on the right side of the weld indicates that a pipe is present in this east rail.

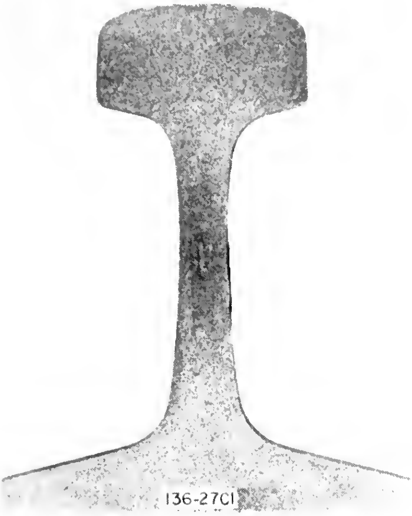


Fig. 15 (west rail)—Sound steel.

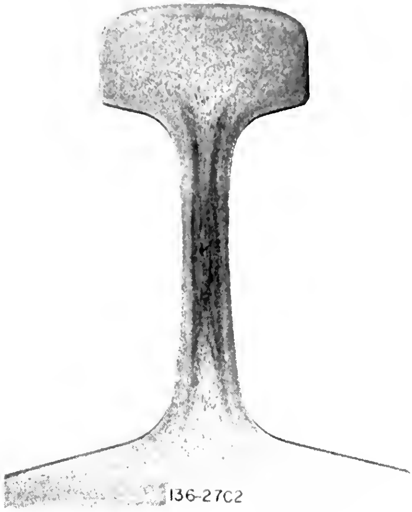


Fig. 16 (east rail)—Pipe and heavy segregation.

Macrophotographs of transverse sections taken from both sides of electric flash butt welded rail joint 136–27C.

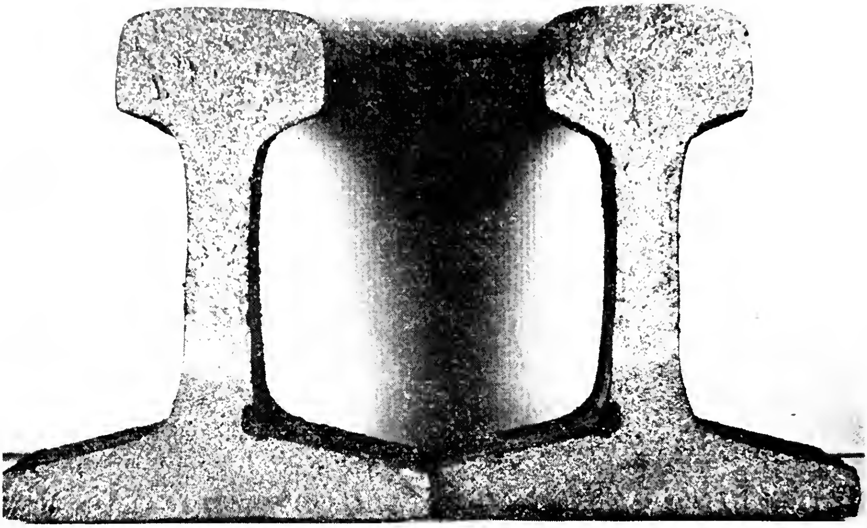


Fig. 17 (Investigation 136–31)—Fractured faces of an Orgotherm thermite welded joint that failed in service. It can be noted that this failure originated in the fillet between the web and base as indicated by the presence of a fatigue ring development.

Fig. 18 (Investigation 136–31)—Photomicrograph of a specimen that was cut through the fatigue ring development shown in Fig. 17. It can be noted that a layer of martensite was round at the origin of this failure. This martensite formation is the result of a heavy grinding of the collar after the thermite weld metal had cooled.

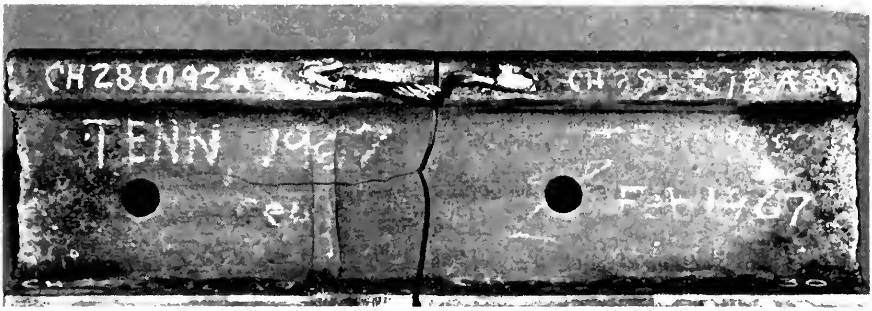


Fig. 19 (Investigation 136—34)—Side view of an electric flash butt welded rail joint that failed in service. This failure started at the weld and progressed in a horizontal plane along the neutral axis, then veered toward the head and base in rail CH28C092-A-30. The Cadweld bond noted on the side of the rail head was affixed after the failure occurred to complete the track signal block circuit until the rail could be removed.

Fig. 20 (28C092-A-9)—Light segregation.

Fig. 21 (28C092-A-30)—Heavy segregation.

Macrophotographs of transverse sections cut from both sides of electric flash butt welded rail joint 136-34. These specimens were etched in a hot 50 percent aqueous solution of hydrochloric acid.

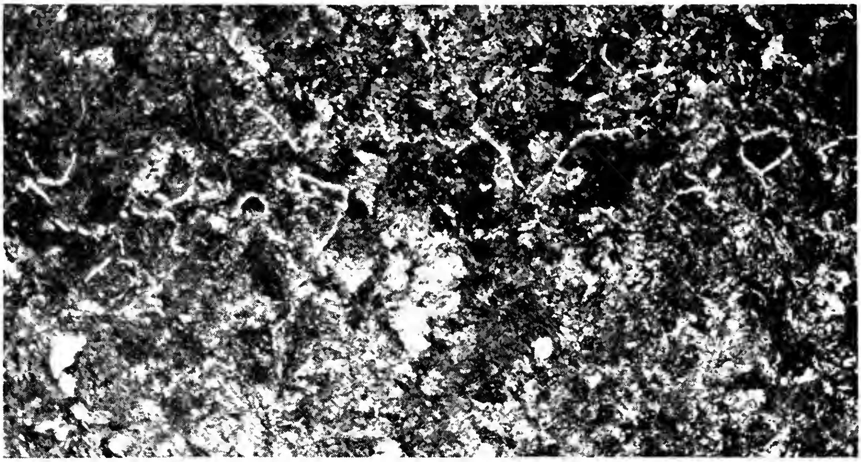


Fig. 22 (Investigation 136-34)—Photomicrograph of a specimen taken adjacent to the fracture showing the microstructure at the weld interface. The presence of cementite, outlining the austenitic grains in the fusion zone, can be noted at magnification of 100X. Etchant 3 percent nital.

Fig. 23 (Investigation 136-34)—Same specimen as in Fig. 22 after being repolished and etched with an alkaline sodium picrate. The presence of cementite, outlining the grain boundries in the fusion zone, can be noted at a magnification of 100X.

PART 2

RESULTS OF ROLLING-LOAD AND SLOW-BEND TESTS OF BUTT WELDED RAIL JOINTS

In the period between October 1, 1966 and October 1, 1967, there were 22 rolling-load tests conducted on butt welded rail joints at the Association of American Railroads Research Center. During this period there were no slow-bend tests conducted on butt welded rail joints. These butt welded rail joints were made by the oxyacetylene and electric flash butt welding process.

The rolling-load tests were made on a 12-in-stroke rolling-load machine. A diagram showing the loading arrangement for this machine can be found in Fig. 1.

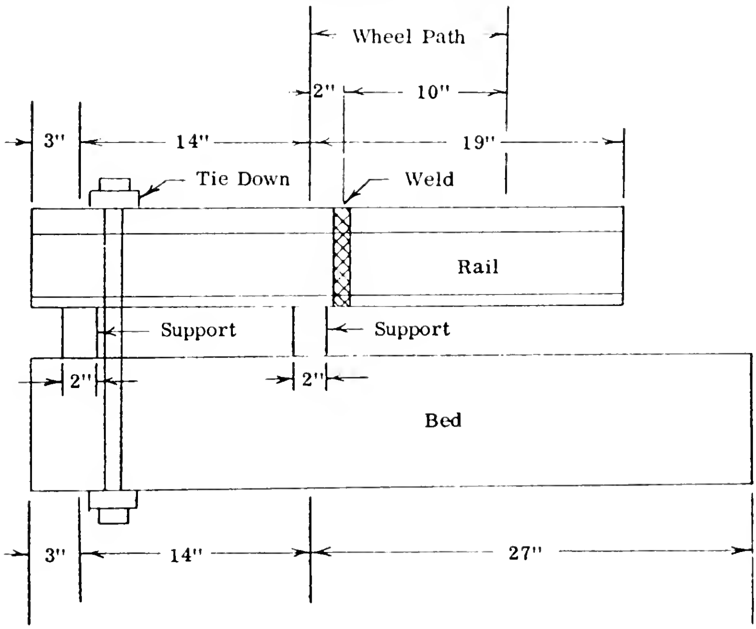


Fig. 1—Diagram showing the loading arrangement for the 12-in-stroke rolling-load machine.

This cantilever arrangement subjects the head of the welded rail to repeated loadings from zero to a maximum tension stress. The applied wheel load for these rolling-load machine tests is dependent on the rail section being tested. In this type of testing, 2,000,000 cycles of repeated loadings without failure is considered a run-out. A summary of the rolling-load test can be found in Table 1.

Investigation 214 (samples A through F) was conducted to determine the seriousness of hairline cracks (segregation and pipe) on oxyacetylene pressure butt weld quality. For this investigation six 100-lb oxyacetylene pressure butt welded joints made from rails having the hairline cracks were prepared by the Seaboard Air Line Railroad (now part of the Seaboard Coast Line Railroad) and submitted for fatigue testing in the 12-in-stroke rolling-load machine. Five of the six joints withstood 2,000,000 cycles of repeated loadings without failure, which is considered a run-out, and one joint (214E) failed after 897,100 cycles. The fractured faces of this failed oxyacetylene pressure butt welded joint can be noted in Fig. 2. A macroscopic examination made on transverse sections cut from the end of each rail prior to welding indicates that this failure originated from a fishtail. Photographs of the macro-etched transverse sections can be found in Figs. 3 and 4.

Investigation 220 (samples A through F) is a continuation of the problem presented in investigation 214 but was conducted to determine the effects of hairline cracks on joints made from rails of heavier sections. For this investigation six 132-lb oxyacetylene pressure butt welded joints made from rails having these hairline cracks were prepared by the Norfolk & Western Railway and submitted for fatigue testing in the 12-in-stroke rolling-load machine. All six of these joints withstood the 2,000,000 cycles minimum requirement without failure.

The problem of hairline cracks located in the rail web was further investigated to determine what effects these imperfections have on electric flash butt weld quality. For this investigation (No. 225, samples A through J) ten 132-lb RE electric flash butt welded joints were prepared by the Erie Lackawanna Railroad and submitted for fatigue testing in the 12-in-stroke rolling-load machine. Seven of the ten joints withstood 2,000,000 cycles of repeated loading without failure, which is considered a run-out. The three joints that failed (225C, E and F) ran 1,438,400; 956,500 and 1,624,300 cycles of repeated loadings, respectively, before failure. Photographs showing the fractured faces of the failed specimens can be found in Figs. 5, 6, 7 and 8. It was found that the fatigue failures originated in the fillet between the head and web and can be attributed to a shear drag introduced while removing the weld upset.

Investigation 226 (samples A and B) was conducted at the request of the Southern Pacific Company to evaluate two electric flash butt welded joints from which the upset metal had been ground from the top and sides of the head and bottom and sides of the base but not removed from the web. This request came as a result of observations made by the SP personnel while on the Hamersley Iron Railroad in Australia. For this investigation two joints made from 132-lb headfree rail were submitted for fatigue testing in the 12-in-stroke rolling-load machine. From this testing, joint 226A failed after 1,682,100 cycles of repeated loading and joint 226B withstood the 2,000,000-cycle minimum requirement without failure. A photograph showing the fractured face of joint 226A can be found in Fig. 9. It can be noted that a pipe is present in the web of these rails, but it is believed that this did not contribute to the failure. An examination of the fracture surface to determine the fracture mechanics indicates that this failure originated in the fillets between the web and upset metal. The origin of this fracture is marked with arrows in the close-up view shown in Fig. 10.

Investigation 230 (samples A and B) was conducted to evaluate oxyacetylene pressure butt welded joints made with a new type of welding head. For this investigation two 112-lb RE (secondhand) oxyacetylene pressure butt welded joints prepared by the Illinois Central Railroad were submitted for fatigue testing in the 12-in-stroke rolling-load machine. From this testing joint 230A failed after 33,500 cycles of repeated loading and joint 230B withstood the 2,000,000 cycle minimum requirement without failure. A photograph showing the fractured faces of this failed joint can be found in Fig. 11. This failure can be attributed to the lack of fusion at the weld interface.

TABLE 1
ROLLING LOAD TEST RESULTS OF BUTT WELDED RAIL JOINTS
AAR Research Center (October 1, 1966 to October 1, 1967)

Specimen No.	Rail Section Lb. Yd.	Type of Weld	Supplied or Welded by	Rolling Load Machine Stroke	Wheel Load (Lbs.)	Number of Cycles	Remarks
214A*	100 lb RE	Oxyacetylene pressure butt weld (rails with hairline cracks in web).	SAL RR	12 in	40,000	2,009,900	No failure.
214B*	100 lb RE	Oxyacetylene pressure butt weld (rails with hairline cracks in web).	SAL RR	12 in	40,000	2,000,000	No failure.
214C	100 lb RE	Oxyacetylene pressure butt weld (rails with hairline cracks in web).	SAL RR	12 in	40,000	2,000,000	No failure.
214D*	100 lb RE	Oxyacetylene pressure butt weld (rails with hairline cracks in web).	SAL RR	12 in	40,000	2,010,100	No failure.
214E*	100 lb RE	Oxyacetylene pressure butt weld (rails with hairline cracks in web and fishtail in head).	SAL RR	12 in	40,000	897,100	Failure originated from fishtail in head and progressed through weld.
214F	100 lb RE	Oxyacetylene pressure butt weld (rails with hairline cracks in web).	SAL RR	12 in	40,000	2,003,000	No failure.
220A	132 lb RE	Oxyacetylene pressure butt weld (rails with hairline cracks in web).	N&W RR	12 in	57,500	2,000,000	No failure.
220B	132 lb RE	Oxyacetylene pressure butt weld (rails with hairline cracks in web).	N&W RR	12 in	57,500	2,000,400	No failure.
220C	132 lb RE	Oxyacetyelene pressure butt weld (rails with hairline cracks in web).	N&W RR	12 in	57,500	2,004,500	No failure.
220D	132 lb RE	Oxyacetylene pressure butt weld (rails with hairline cracks in web).	N&W RR	12 in	57,500	2,000,000	No failure.
220E	132 lb RE	Oxyacetylene pressure butt weld (rails with hairline cracks in web).	N&W RR	12 in	57,500	2,066,200	No failure.
220F	132 lb RE	Oxyacetylene pressure butt weld (rails with hairline cracks in web).	N&W RR	12 in	57,500	2,000,000	No failure.
225A	132 lb RE	Electric flash butt weld (rails with hairline cracks in web).	Erie-Lack RR	12 in	57,500	2,000,200	No failure.
225B	132 lb RE	Electric flash butt weld (rails with hairline cracks in web).	Erie-Lack RR	12 in	57,500	2,000,000	No failure.
225C	132 lb RE	Electric flash butt weld (rails with hairline cracks in web).	Erie-Lack RR	12 in	57,500	1,438,400	Fatigue failure originating in the fillet between the head and web from a shear drag.
225D	132 lb RE	Electric flash butt weld (rails with hairline cracks in web).	Erie-Lack RR	12 in	57,500	2,000,000	No failure.
225E	132 lb RE	Electric flash butt weld (rails with hairline cracks in web).	Erie-Lack RR	12 in	57,500	956,500	Fatigue failure originating in the fillet between the head and web from a shear drag.
225F	132 lb RE	Electric flash butt weld (rails with hairline cracks in web).	Erie-Lack	12 in	57,500	1,624,300	Failure originated in the fillet between the head and web from a shear drag.
225G	132 lb RE	Electric flash butt weld (rails with hairline cracks in web).	Erie-Lack RR	12 in	57,500	2,000,900	No failure.
225H	132 lb RE	Electric flash butt weld (rails with hairline cracks in web).	Erie-Lack RR	12 in	57,500	2,000,000	No failure.
225I	132 lb RE	Electric flash butt weld (rails with hairline cracks in web).	Erie-Lack RR	12 in	57,500	2,000,000	No failure.
225J	132 lb RE	Electric flash butt weld (rails with hairline cracks in web).	Erie-Lack RR	12 in	57,500	2,000,000	No failure.
226A	132 lb HF	Electric flash butt weld (upset metal removed from top and sides of head and bottom and sides of base but not removed from either side of web).	SP Co.	12 in	57,500	1,682,100	Failure originated from weld upset just below the head-web fillet and progressed through the web at a 45° angle.
226B	132 lb HF	Electric flash butt weld (upset metal removed from top and sides of head and bottom and sides of base but not removed from either side of web).	SP Co.	12 in	57,500	2,000,000	No failure.
230A	112 lb RE (second-hand)	Oxyacetylene pressure butt welds (welds made with a new type of welding head).	IC RR	12 in	47,500	33,500	Broke through weld interface - no fusion in portion of head.
230B	112 lb RE (second-hand)	Oxyacetylene pressure butt welds (welds made with a new type of welding head).	IC RR	12 in	47,500	2,000,300	No failure.

*These welded joints were tested and reported last year and included for information.

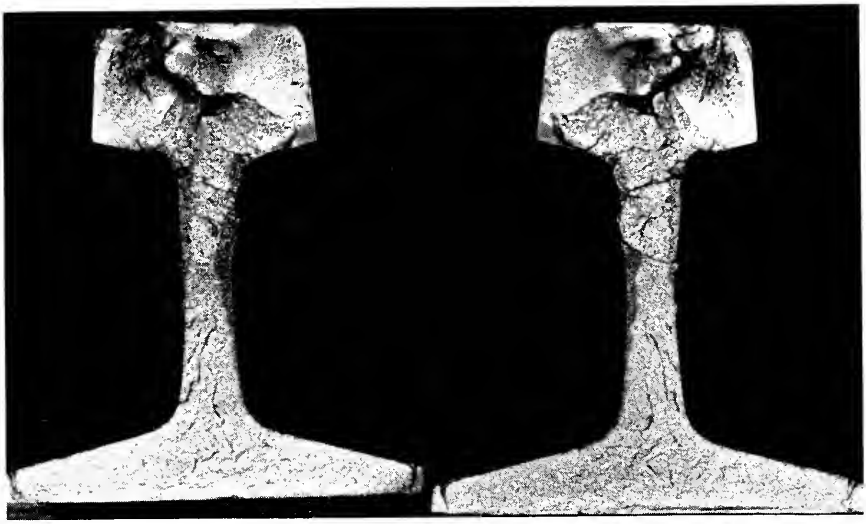


Fig. 2—Fractured faces of an oxyacetylene pressure butt welded rail joint, specimen 214E, that failed after being subjected to 897,100 cycles of repeated loading in the 12-in-stroke rolling-load machine under a 40,000-lb wheel load. This failure originated from a fishtail in the head of one rail. Macro-etched transverse sections showing the internal condition of the two rails used to make this joint can be seen in Figs. 3 and 4.

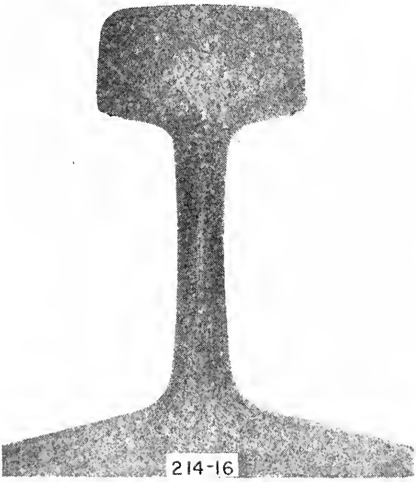


Fig. 3.

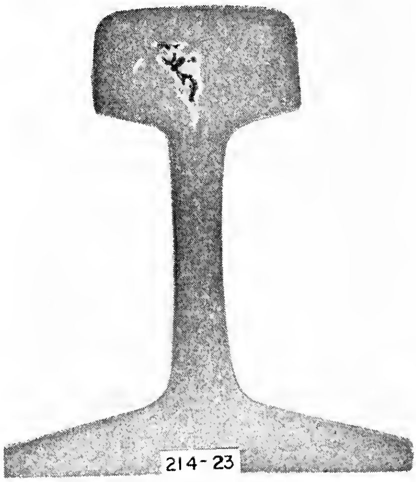


Fig. 4.

Photographs showing the macro-etched transverse sections taken from rails, abutted ends, prior to welding. The fractured faces of this experimental pressure butt welded joint, specimen 214E, is shown in Fig. 2. These sections etched in a hot 50 percent aqueous solution of hydrochloric acid shows a pipe in the web of section 214–16 (Fig. 3) and a fishtail in the head of section 214–23 (Fig. 4).

Fig. 5—Fractured faces of electric flash butt welded rail joint, specimen 225C, that failed after being subjected to 1,438,400 cycles of repeated loading in the 12-in stroke rolling-load machine under a 57,500-lb wheel load. This fatigue failure originated in the fillet between the head and web and is the result of a shear drag.

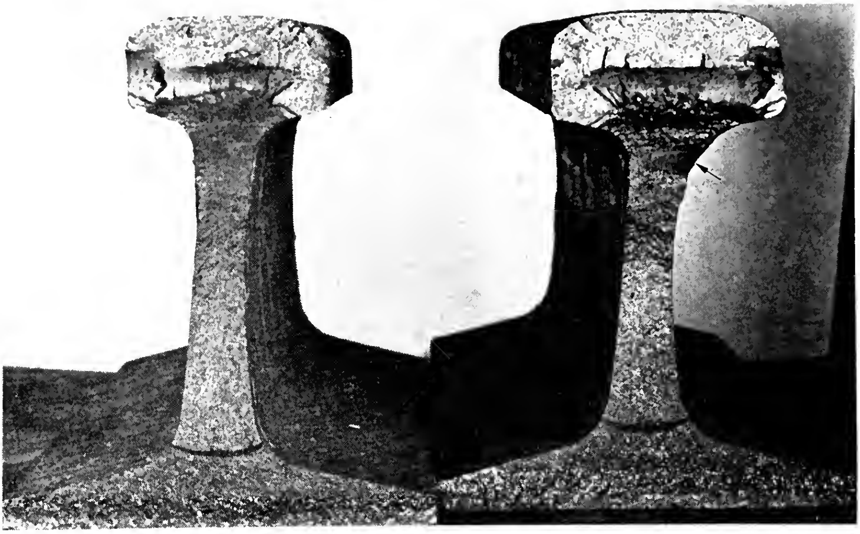


Fig. 6—Fractured faces of an electric flash butt welded rail joint, specimen 225E, that failed after being subjected to 956,500 cycles of repeated loading in the 12-in-stroke rolling-load machine under a 57,500-lb wheel load. This failure originated in the fillet between the head and web, marked with an arrow in photograph, and is the result of a shear drag.

Fig. 7—Close-up view of the area marked with an arrow in Fig. 6 showing the origin of this fatigue failure.

Fig. 8—Photograph showing the surfaces of a crack that developed in an electric flash butt welded rail joint, specimen 225F, after being subjected to 1,624,300 cycles of repeated loading in the 12-in-stroke rolling-load machine under a 57,500-lb wheel load. This fracture originated from a shear drag in the fillet between the head and web, marked with an arrow in the above photograph, and progressed along a horizontal plane with termination at the head and base fillets. The fractured surfaces were made visible by cutting through the head and base to separate this web crack.

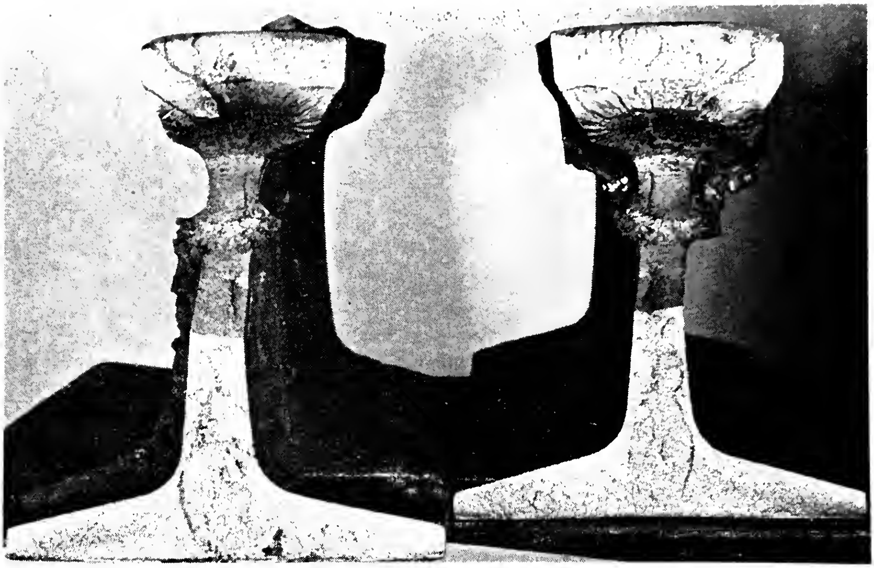


Fig. 9—Fractured faces of an electric flash butt welded rail joint, specimen 226A, that failed after being subjected to 1,682,100 cycles of repeated loading in the 12-in-stroke rolling-load machine under a 57,500-lb wheel load. It can be noted that a pipe is present in the web of these rails, but an analysis of the fracture mechanics indicates that this failure originated in the fillets between the web and upset metal.

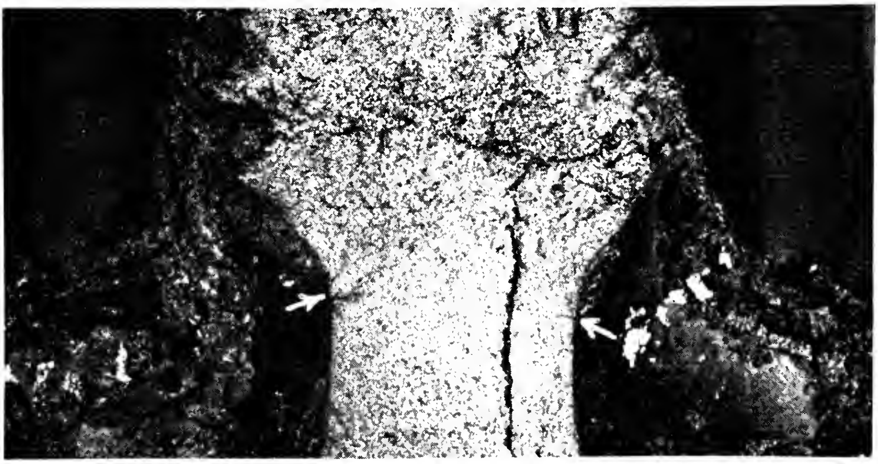


Fig. 10—Close-up view of the fracture shown in Fig. 9. This fracture originated from the areas marked with an arrow.

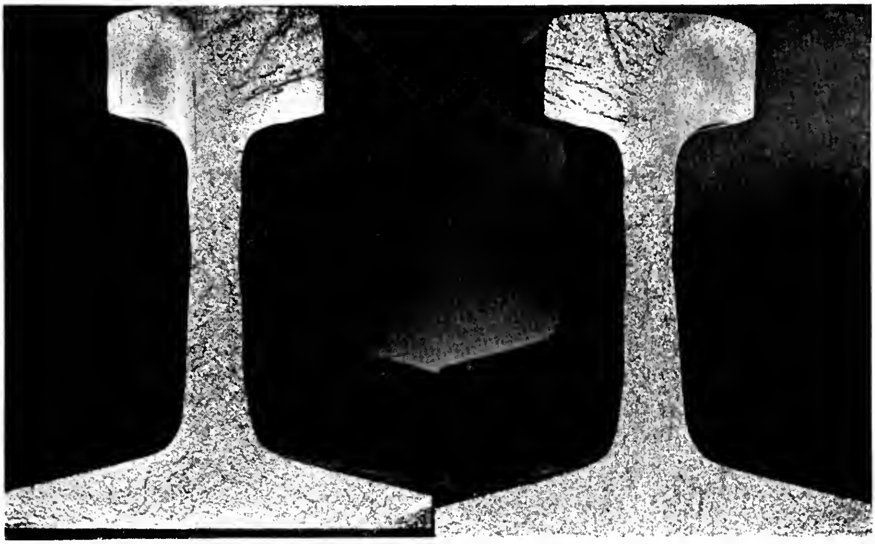


Fig. 11—Fractured faces of an oxyacetylene pressure butt welded rail joint, specimen 230A, that failed after being subjected to 33,500 cycles of repeated loading in the 12-in-stroke rolling-load machine under a 47,500-lb wheel load. This failure can be attributed to a lack of fusion at the weld interface (unfused area noted in head) thereby resulting in a weakened structure.

PART 3

BUTT WELD FAILURES

In 1962, it was decided that it would be desirable to have a record of failures in the different types of butt welds. Accordingly, Form 402E was prepared to develop the desired information. Table 1 shows the accumulated failures to December 31, 1966. This table is a summary of Form 402E which shows the failures by railroads and weight of rail and a more detailed analysis can be made later if desired. For the present it appears that the data shown in this table will give the information desired. It will be noted from Table 1 that on the basis of failures per 100 weld years, the failure rates for the oxyacetylene pressure butt welds and electric flash pressure butt welds are low, and about the same, for new rail. It should be noted, however, that the average service period of the oxacetylene pressure butt welds is 64 percent longer than that of the electric flash pressure butt weld. For relay rail, the performance of the electric flash pressure weld is somewhat better than that of the oxyacetylene pressure weld. The performance is quite good for both types, however, because the highest failure rate of 0.0218 for the oxyacetylene pressure weld on relay rail would only be equivalent to about one failure in 16 miles of track per year.

The failure rate in thermite welds is substantially higher than that for either of the two pressure processes. The failure rate shown for thermite welds of new rail is equivalent to one failure in 175 welds per year.

TABLE 1
ACCUMULATED BUTT WELD FAILURES TO DECEMBER 31, 1966

		Number of Welds	Weld Years	FAILURES			Failures per 100 Weld Years	Average Weld Age Years
				Service	Detected	Total		
Flash Pressure Butt Weld	New Rail	1,602,788	6,609,402	311	58	369	0.0056	4.12
	Relay Rail	551,401	1,440,611	200	32	232	0.0161	2.61
Oxyacetylene Pressure Butt Weld	New Rail	667,122	4,510,850	191	80	271	0.0060	6.76
	Relay Rail	238,327	610,552	113	20	133	0.0218	2.56
Thermit Weld	New Rail	4,826	28,713	151	13	164	0.5712	5.95
	Relay Rail	2,692	9,543	34	1	35	0.3668	3.54

Report on Assignment 2

Laying

O. E. Fort (chairman, subcommittee), W. D. Almy, E. J. Brown, R. M. Brown, E. M. Cummings, E. Eskengren, B. J. Gordon, J. W. Harper, J. C. Hunsberger, T. B. Hutcheson, H. W. Jenkins, B. J. Johnson, C. W. Law, Jr., M. S. Reid, C. W. Wagner, E. H. Waring.

Your committee submits, as information, the following statistics on the number of track miles of CWR laid, by years, since 1933.

Track Miles of Continuous Welded Rail Laid by Years, 1933–1967

			Oxy-acetylene	*Electric Flash*	*Total*
1933	0.16				
1934	0.95				
1935	4.06				
1936	1.52	1955	194.50	72	266.50
1937	31.23	1956	372.33	89.10	461.43
1939	6.04	1957	390.47	159.65	550.12
1942	5.48	1958	148.11	312.13	460.24
1943	6.29	1959	378.65	691.92	1070.57
1944	12.88	1960	299.42	961.20	1260.62
1945	1.81	1961	94.13	926.50	1020.63
1946	3.91	1962	310.59	1183.34	1493.93
1947	18.70	1963	497.52	1360.48	1858.00
1948	29.93	1964	586.76	1796.74	2383.50
1949	33.05	1965	700.59	1655.74	2356.33
1950	50.25	1966	746.61	1984.71	2731.32
1951	37.25	1967	784.28	1800.27	2584.55
1952	40.00				
1953	80.00				18951.25
1954	87.09				

Break-Down of Continuous Welded Rail Laid in 1967—Track Miles

	Oxyacetylene		*Electric Flash*		*Totals*
	New	*Second-Hand*	*New*	*Second-Hand*	
Main Track	412.85	341.60	1150.15	579.19	2483.79
Yard Tracks	8.00	21.83		70.93	100.76
	420.85	363.43	1150.15	650.12	2584.55

Report on Assignment 3

Fastenings

R. E. Frame (chairman, subcommittee), C. M. Bowman, J. E. Campbell, J. D. Case, O. E. Fort, R. G. Garland, B. J. Gordon, J. W. Harper, F. E. Huddleston, B. J. Johnson, G. G. Knupp, J. A. MacNab, C. R. Merriman, C. E. Morgan, R. H. Patterson, R. P. Roden, A. E. Shaw, Jr., T. C. Shedd, C. W. Wagner.

In 1966 a field test was set up by the AAR Research Department with the objective of designing and recommending a minimum anchorage pattern for CWR. A progress report was presented last year in Bulletin 605, page 402.

Your committee now submits, as information, a progress report covering the work done in 1967.

PROGRESS REPORT ON ANCHORAGE OF CONTINUOUS WELDED RAIL

Description of Test

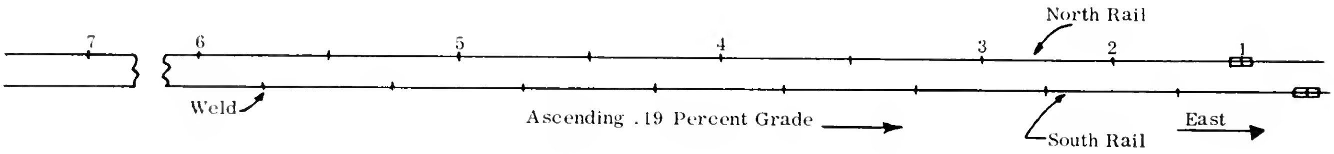
On May 16, 1967, measurements were made on the test installation for the study of rail anchorage for continuous welded rail on the Illinois Central Railroad west of Burlington, Ill. at Mile Post 57.15 (Fig. 1). The day was sunny with a

Fig. 1—Test location for study of rail anchorage forces on continuous welded rail.

slight breeze. Rail temperatures are shown in the data obtained. The purpose was to obtain data on (1) the effect of train movements on rail anchorage forces (static before and after) and (2) the relation between rail anchorage force and tie movement.

This installation is on tangent track with 115 RE continuous welded rail. There are 24 ties per 39-ft rail length. The tie plates are double-shoulder 7¾ by 13 in. Only two line spikes are used per plate. The ballast is crushed blast-furnace slag and there was little shoulder at the location of measurement. The rail anchors are

FIG. 2
PLAN OF TEST STATIONS NEAR BURLINGTON, ILLINOIS



Station No. 1 - at joint connecting two 1/4 mile welded sections

Station No. 2 - one rail length west of joint

Station No. 3 - two rail lengths west of joint

Station No. 4 - four rail lengths west of joint

Station No. 5 - six rail lengths west of joint

Station No. 6 - eight rail lengths west of joint

Station No. 7 - eighteen rail lengths west of joint and mid-point of welded section

All stations on north rail

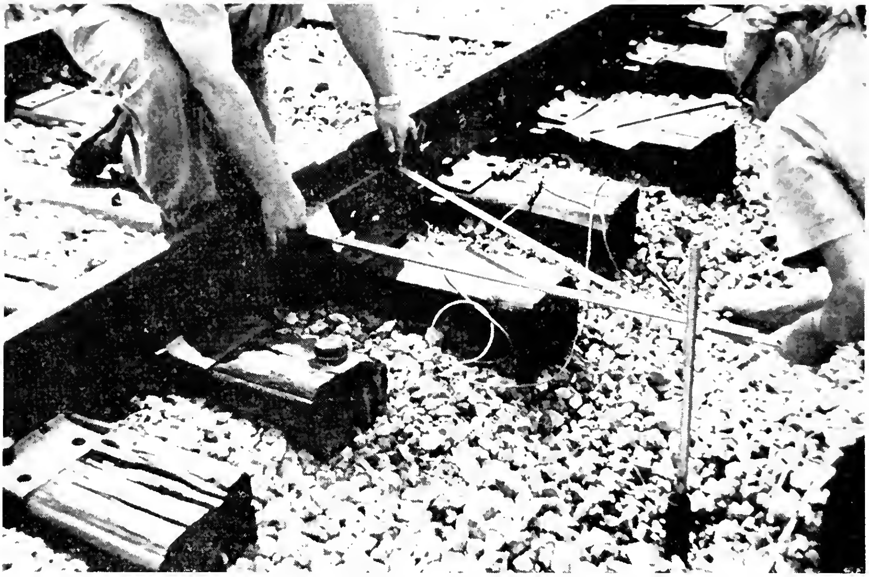


Fig. 3—Measuring longitudinal movement of rail with respect to reference pipe at each test station.

the improved Gautier type and every third tie is boxed throughout the rail length. At the connecting joints, the two intervening ties have rail anchors applied to resist opening of the joint gap for six rail lengths on each side of the joint. The rail joints are six-hole with 1-in-diameter bolts.

A rail joint was selected for test measurements in the north rail. This was not an insulated joint. All measurements were taken on the north rail west of this joint. Test Station No. 1 was just west of the joint; Station No. 2 was 1 rail length west; Station No. 3 was 2 rail lengths west; Station No. 4 was 4 rail lengths west; Station No. 5 was 6 rail lengths west; Station No. 6 was 8 rail lengths west; and Station No. 7 was at the mid-length of the welded string, 18 rail lengths west. The accompanying diagram (Fig. 2) shows the test locations.

At each test station, a reference pipe was driven in the roadbed for measuring the longitudinal movement of the rail. Fig. 3 is a photograph showing how this measurement was obtained. Also, strain-gage holes were drilled in the rail web at the neutral axis to measure the longitudinal stress in the rail with a 20-in Berry strain gage. A length of rail head was used as a reference bar to adjust the dial setting and correct for the effect of temperature. The reference bar (rail head) was kept at the same temperature as the rail, and since it always had zero longitudinal stress, it was only necessary to keep the dial setting at the same reading when the strain gage was checked on the reference bar. When applied to the rail in track, any difference between the reading obtained and previous readings would represent change in longitudinal stress. Fig. 4 shows the method of making this measurement.

The amount of restraining force applied to the rail by the rail anchor and the tie was determined for a number of ties at each test location except Station No. 7,

Fig. 4—Measuring longitudinal stress in rail with 20-in Berry strain gage.

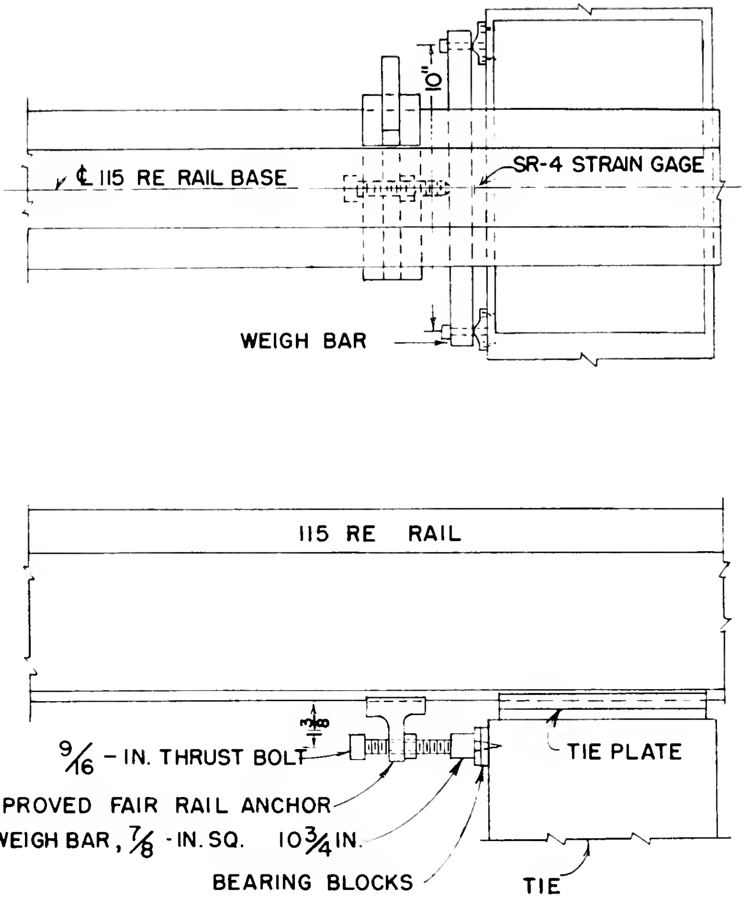


FIG. 5 PLAN OF WEIGH BAR FOR MEASURING RAIL RESTRAINING FORCES

at which location the weigh bars were not yet installed. The weigh bars were applied at the top edge of the tie with a rounded support at each end. The weigh bars are 10 in long by $\frac{7}{8}$ in square in cross section and are of heat-treated steel. They were calibrated in the laboratory and found to be linear in load-stress ratio up to an applied load of 3500 lb. A hole was drilled in an improved Fair rail anchor and threaded for a $\frac{9}{16}$-in diameter bolt with lock nut at the mid-width of the rail base. This hole was located so the end of the bolt would bear against the mid-length and mid-width of the weigh bar. A strain gage applied on the back side of the weigh bar was used to measure the applied force. The weigh bars, as calibrated in the laboratory, registered a flexural strain of 80 micro inches for each

Fig. 6—Extensometers measuring longitudinal movement of tie and rail weigh bars on ties which measure longitudinal rail forces applied to them.

100 lb of applied force. Fig. 5 is a diagram showing the rail anchor and weigh bar construction and Fig. 6 shows the application to a test tie in track.

The rail temperature was measured with a mercury-bulb type rail thermometer and the joint gap opening was measured with a scale graduated to 0.01 in. Fig. 7 shows the location of the ties at each test location which were selected for making the measurements of rail anchor force.

Test Procedure

The first train was expected at 10:30 am, so first all weigh bars were loosened to obtain zero readings and the 100-lb force was applied to eastbound anchors (anchors to restrain easterly rail movement). All westbound anchors had the bolts adjusted to just be in contact. The joint gap and rail temperature were measured periodically. Also, the rail position lengthwise of the track was measured at each test location. These measurements were then repeated after each of four trains had passed to show the change that had been effected by the train passage.

Discussion of Test Results

The first train, an eastbound passenger train, passed at high speed at 10:45 am. The following effects were noted (Table 1):

(1) Joint Gap—The joint gap was 0.50 in at 8:40 am (rail temperature 58°) and had not changed by 10:45 am at which time the rail temperature was 73°. After the train passage the joint gap was 0.44 in, a reduction of 0.06 due to the train passage.

TABLE I

MEASUREMENTS OF JOINT GAP, RAIL MOVEMENT, AND ANCHOR FORCES

	Before Trains	After E. B. Pass.	After W. B. Pass.	After 1st E. B. Freight	After 2nd E. B. Freight	After Joint Closed
Time	8:40 am	10:45 am	11:13 am	12:45 pm	1:12 pm	3:50 pm
Rail Temperature	58°	73°				87°
Sta. #1-Joint Gap (in)	0.50	0.44	0.37	0.27	0.24	0.0
Rail Movement (in)		0.06(E)	0.08(W)	0.18(E)	0.01(E)	0.09(E)
Load (lb)-Rail Anchor #1W	0	0	0	232x	232x	224x
#2E	100	29	25	162	195	751
#3W	0	0	0	204x	201x	188x
#4W	0	0	0	190x	202x	172x
#5W	0	0	0	74x	201x	195x
#6E	100	311	110	650	501	1356
#7W						
#8W	0	0	0	189x	210x	170x
#9E	100	259	65	387	325	200 ?
Sta. #2-Rail Move. (in)		0.08(E)	0.06(W)	0.16(E)	0.02(E)	0.07(E)
Load (lb)-Rail Anchor #2W	0	0	0	202x	204x	204x
#3E	100	106	25	145	80	719 ?
#4W	0	0	0	188x	170x	182x
#6E	100	162	57	146	86	294
Sta. #3-Rail Move. (in)		0.07(E)	0.06(W)	0.17(E)	0.00	0.06(E)
Load (lb)-Rail Anchor #1W	0	0	0	240x	238x	246x
#2E	100	82	19	174	216	730
#3W	0	0	61	194x	192x	188x
#4W	0	0	0	195x	197x	185x
#5E	100	325	61	701	631	1220
Sta. #4-Rail Move. (in)		0.07(E)	0.06(W)	0.13(E)	0.02(E)	0.01(E)
Load (lb)-Rail Anchor #1W			199	0	0	11
#2E			0	800	882	1198
#3W			212	0	0	16
#4E			0	450	421	558
Sta. #5-Rail Move. (in)				0.14(E)		0.04(E)
Load (lb)-Rail Anchor #1W				209x	200x	190x
#2E				79x	54x	27x
#3W				196x	186x	179x
#4E				365	410	582
Sta. #6-Rail Move. (in)				0.12(E)		0.02(E)
Load (lb)-Rail Anchor #1W				204x	195x	176x
#2E				15	21	88x
Sta. #7-Rail Move. (in)				0.01(E)		0.02(E)
Time						4:20 pm
Rail Temperature						85°

(2) Rail Movement—The train passage moved the rail 0.06 in east at Station No. 1; 0.08 in east at Station No. 2; 0.07 in east at Station No. 3; and 0.07 in east at Station No. 4. Time was not available before the next train for measurement at the other stations.

(3) Rail Anchor Forces—At Station No. 1, anchor 2E lost 71 lb of its 100 lb applied pressure, but anchor 6E increased its applied pressure by 211 lb from 100 lb to 311 lb. Anchor 9E increased its applied pressure by 159 lb from 100 lb to 259 lb. The westbound anchors showed no change from zero force.

(4) At Station No. 2, anchor 3E increased its applied pressure of 100 lb to 106 lb and anchor 6E from 100 lb to 162 lb. The westbound anchors continued at zero force.

(5) At Station No. 3, the applied pressure on anchor 2E decreased from 100 lb to 82 lb but on anchor 5E it increased from 100 lb to 325 lb. Time was not available to make measurements at Stations No. 4, No. 5 and No. 6.

The second train, a high-speed westbound passenger train, passed at 11:13 am. The following results were obtained:

(1) Rail Movement—At Station No. 1, the rail moved 0.08 in west; at Station No. 2, 0.06 in west; at Station No. 3, 0.06 in west; and at Station No. 4, 0.06 in west.

(2) Rail Anchor Forces—At Station No. 1 there was little change in anchor 2E, but anchors 6E and 9E lost the added pressure from the eastbound passenger train, reducing to 110 lb and 65 lb applied force, respectively. Westbound anchors remained unloaded.

(3) At Station No. 2, anchor 3E dropped 81 lb to 25 lb applied pressure, and anchor 6E dropped 105 lb to 57 lb applied pressure. Westbound anchors remained unloaded.

(4) At Station No. 3, anchor 2E dropped to 19 lb applied pressure; anchor 3W increased to 61 lb; and anchor 5E dropped to 61 lb. Westbound anchors remained unloaded.

(5) At Station No. 4, the anchors were set up snug prior to the arrival of the westbound passenger train. After the train had passed, anchor 1W increased to 199 lb and anchor 3W increased to 212 lb. Anchors 2E and 4E were unloaded.

The third train was an eastbound freight with three diesel units and 69 cars running at a speed estimated at 40 mph. The rail moved 0.18 east at Station No. 1; 0.16 east at Station No. 2; 0.17 east at Station No. 3; and 0.13 east at Station No. 4. Time was not available for measurements at Stations No. 5 and No. 6, but little movement occurred at any time at Station No. 7. Since the joint gap only closed 0.10 in, it is evident that there was some movement due to compressive forces set up in the west end of the adjoining rail to the east. Measurements were made of the anchor forces as shown in Table 1, but at the time it was not realized that an appreciable drift had occurred in the weigh-bar gages. The values followed by an "x" in Table 1 are negative values for rail anchor force, and since this cannot occur, the values represent drift. On all westbound anchors the values shown are actually for zero force. For the eastbound anchors, the amount that the measured forces were reduced due to a similar drift is unknown. However, it is evident that this eastbound freight left relatively high forces in some of the eastbound anchors, probably in excess of 650 lb at Station No. 1, anchor 6E; and 800 lb at Station No. 4, anchor 2E. Also, it does not appear that the anchor forces were uniform at all eastbound anchors at the same location.

The second eastbound freight had three diesel units and 103 cars and was moving at about the same speed.

As will be noted from Table 1, there were no outstanding changes in measured values. The rail anchor forces in general appeared to decrease somewhat on the eastbound anchors except at Station No. 4 anchor 2E, which increased to 882 lb.

After a series of measurements were made to determine the relation between anchor force and tie movement at Station No. 1 as described later in this report, the joint bolts were loosened at 3:50 pm, with a rail temperature of 87°, and the joint gap snapped shut, closing 0.24 in. Due to this closing the rail was found to have moved 0.09 in east at Station No. 1; 0.07 in east at Station No. 2; 0.06 in east at Station No. 3; and 0.01 in east at Station No. 4. Due to this closure of the joint gap, some relatively large rail anchor forces on the eastbound anchors are indicated in Table 1, for example: as much as 1356 lb at Station No. 1, anchor 6E; 1220 lb at Station No. 3, anchor 5E; and 1198 lb at Station No. 4, anchor 2E. It would be interesting to know whether these forces would be reduced by a train movement, as the tests described later indicated that rail vibration would substantially reduce the tie restraint to rail movement.

Tie Movement Tests

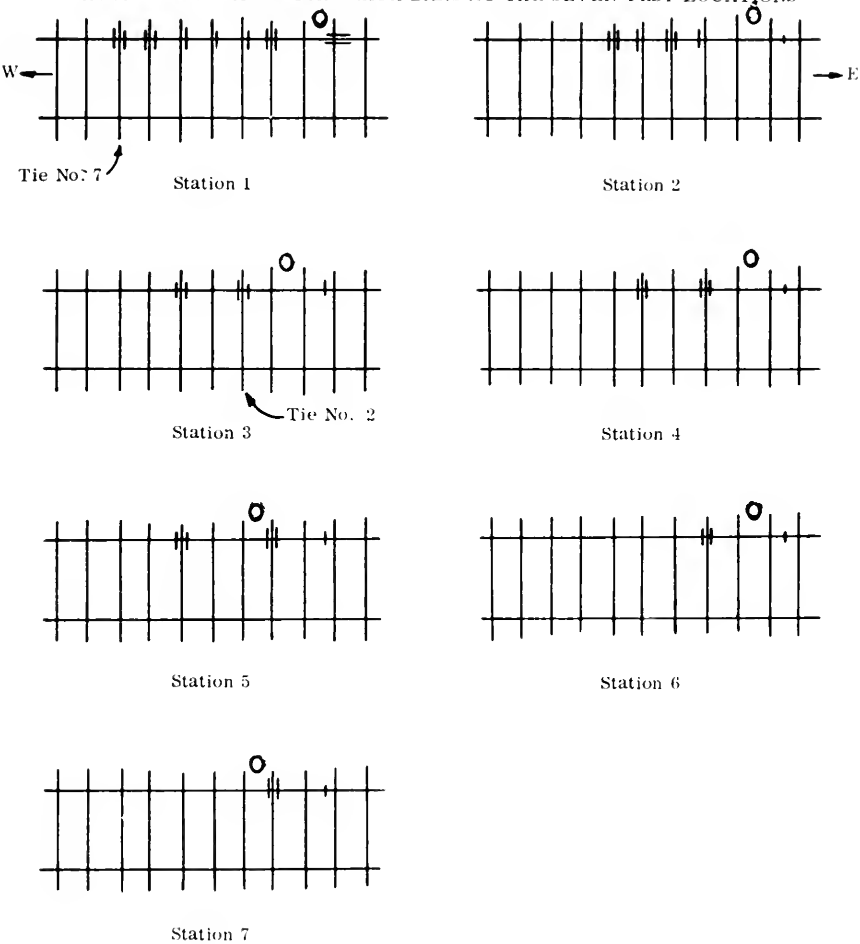
Tests were made to determine the resistance or force required to move the ties in the ballast. At Station No. 1 and on tie No. 7 (Fig. 7) two additional weigh bars were installed under the south rail. Ames dial indicators were installed to measure the movement between the tie and each rail. By adjusting the thrust bolts, loads in increments of 100 and 200 lb were applied through the west weigh bars to the tie. Fig. 8 shows that 2,000 lb applied by each weigh bar (No. 9N and No. 9S) caused the tie to move 0.12 in east. Fig. 8 also shows that a tap on the rail head with a maul caused the tie to move east an additional 0.02 in and caused the load to drop 600 lb. Load was then applied through the east weigh bars (No. 8N and No. 8S), and with a load of 2,000 lb the tie had moved about 0.17 in west as shown in Fig. 9. Fig. 10 shows that a repeat of moving the tie east resulted in a greatly increased movement of the tie when the rail head was tapped 12 times between each increment of loading. This would indicate that under the vibration of train movement, the rail forces exerted on ties by the rail anchors tend to equalize. Static readings on the weigh bars taken at the test stations before and after train movements also show this equalizing of tie forces. When the load was adjusted on all weigh bars to 500 lb and checked several days later, the load on all bars had dropped to less than 50 lb.

A week later a test similar to the one above was repeated at test Station No. 3, with two weigh bars attached to each end of tie No. 2 (Fig. 7). The rail heads were tapped six times with a maul between each set of tie movement readings. The results are shown in Figs. 11 and 12 and are quite similar to those in Figs. 8 and 9. Presumably the relatively greater movement of the tie in Fig. 10 was due to the ties first having been moved east and back west before making this test.

(Text continued on page 612)

FIG. 7

LOCATION OF TIES WITH WEIGH BARS AT THE SEVEN TEST LOCATIONS



Rail anchor weigh bars measuring forces on ties.

Reference pipe to measure longitudinal rail movement.

Weld in rail.

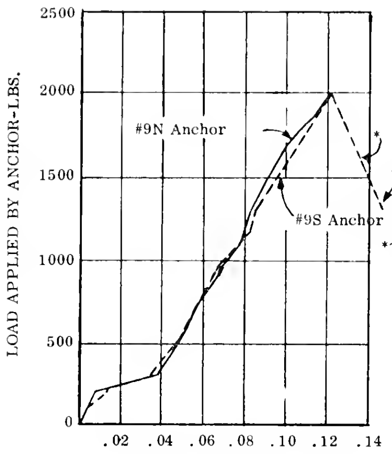


FIG. 8 TIE MOVEMENT EAST-IN.

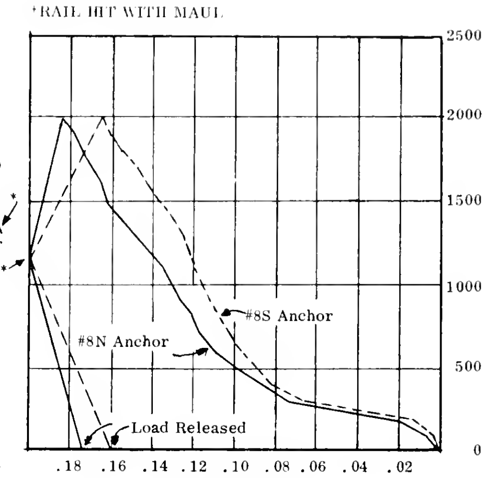


FIG. 9 TIE MOVEMENT WEST-IN.

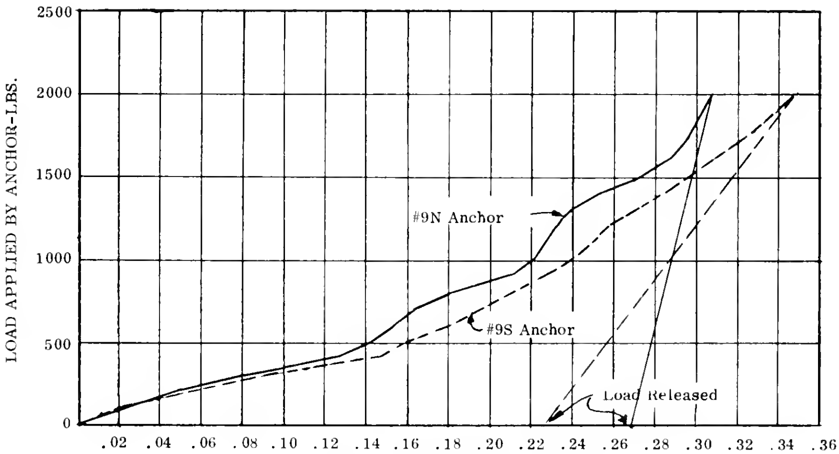


FIG. 10 TIE MOVEMENT EAST-IN.
TAPPING ON GAGE SIDE OF EACH RAIL HEAD WITH A MAUL
12 TIMES BETWEEN EACH READING

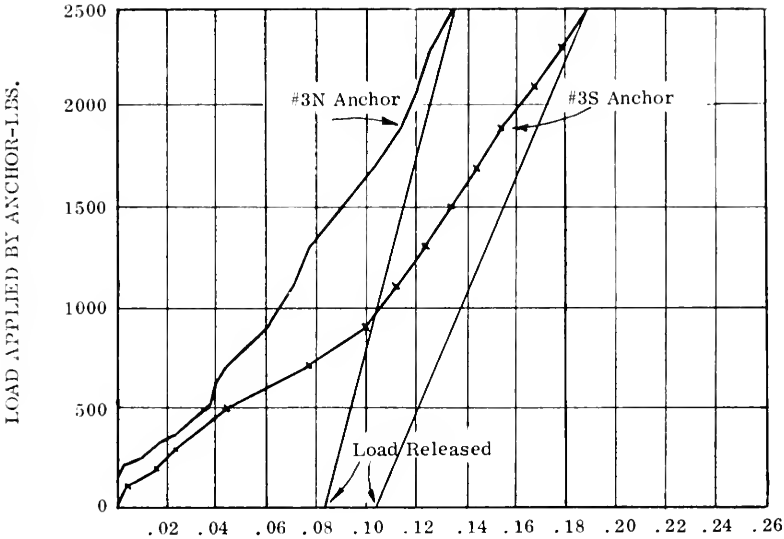


FIG. 11 TIE MOVEMENT EAST-IN

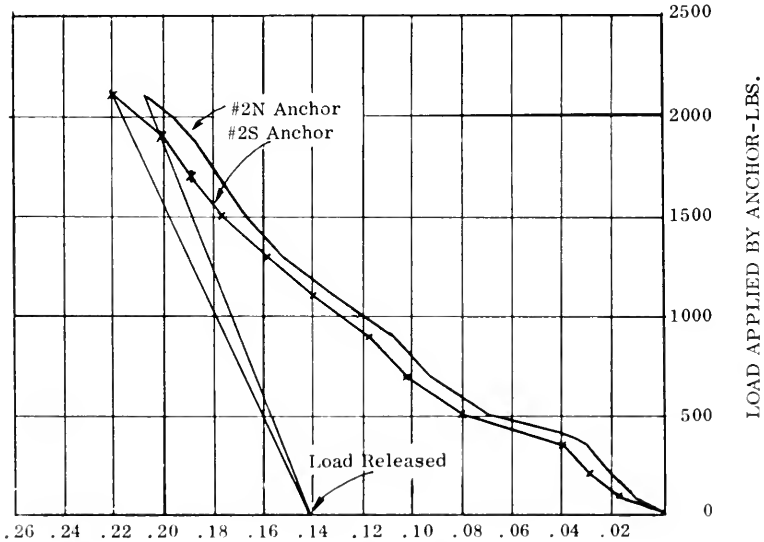


FIG. 12 TIE MOVEMENT WEST-IN.

Rail Anchor Forces Under Trains

In June the AAR Mobile Laboratory truck housing dynamic recording equipment was driven to the test site and information was recorded under all trains during a two-day period. The recording equipment consisted of 12-carrier amplifiers and a direct writing oscillograph. Ten channels recorded the longitudinal rail forces exerted through rail anchors to the weigh bars on the ties. One tie with weigh bars on each side of the tie was selected at each of the first five stations. The remaining two channels, connected to extensometers, were used to measure the longitudinal movement of the rail and the tie with respect to the reference pipe located at Station No. 1. Fig. 6 is a photograph showing the reference pipe, the extensometers and weigh bars.

Station No. 6 and No. 7 were beyond the reach of cables for the recording equipment and, therefore, no data was recorded from the weigh bars at these two locations. Table 2 shows the maximum longitudinal forces in pounds exerted to the weigh bar ties by the passage of freight and passenger trains over the instrumented ties. Before the first run the thrust bolts were adjusted so that they were just contacting the weigh bars; therefore, only one bar could be loaded at a time. However, as in run 2, forces were recorded on both the east and west weigh bars. A study of the recorded traces of run 2 indicates that the west bars were loaded when the trucks were over the weigh bar ties and the east bars took the load between the trucks. As shown in Table 1, after most runs high anchor forces were left in some of the weigh bars. These forces may be increased if the next train movement is in the same direction as the previous run, or reduced to zero if in the opposite direction.

Determination of Rail Anchor Forces

When this study was started it was thought that the rail forces exerted through the anchors to the ties could be measured from time to time by the load in the weigh bars installed on the ties. When the bars were installed the thrust bolts were all adjusted so that they were just making contact with the weigh bars (see Fig. 5). The intention was to read the load in the bars from time to time at low and high rail temperatures during winter and summer. After a number of sets of readings were secured, it was found that the load in the bars was always zero or very low. It was first thought that the ends of the thrust bolts were wearing down and releasing the load. The ends of the thrust bolts were then hardened and the loads again applied and readings taken. The results were the same; the loads were either very small or zero. The only exception was a low spot where last winter the ties were frozen in the ballast.

It was then decided to attempt another approach. A two-pen spring-wound recorder was purchased and installed at joint test Station No. 1, Fig. 13. One pen was used to record the rail temperature through a sensing bulb cemented to the rail and connected to the recorder through a 25-ft capillary tube. This system was factory temperature compensated for a range of $-30°$ to $+150°$ and calibrated to an accuracy of ± 0.5 percent for the entire range. The second pen was connected to a push-pull cable which was fastened to the base of the two rails at the joint to measure the change in the rail gap, Fig. 14. After four weeks of recording, the bolt tension of the joint was checked with a Berry gage, which indicated the bolt tension was about 7,000 lb. Fig. 15 shows the change of rail gap with change of temperature. The inner trace is the joint gap and the outer trace the rail temperature. Small lines across the pen traces indicate passage of trains across the joint.

TABLE 2
MAXIMUM LONGITUDINAL FORCE IN LB EXERTED TO TIES BY PASSAGE OF TRAINS

			Station 1		Station 2		Station 3		Station 4		Station 5	
Run	Time	Train	East Bar	West Bar	East Bar	West Bar	East Bar	West Bar	East Bar	West Bar	East Bar	West Bar
1	10:50A	Eb. Pass.	40	600	40	520	0	600	0	520	0	260
2	11:25A	Wb. Pass.	160	360	160	400	120	260	120	360	0	80
3	1:00P	Eb. Frt.	0	800	40	780	0	760	0	700	0	240
4	2:00P	Eb. Frt.	0	600	80	720	0	680	0	760	0	240
5	4:25P	Eb. Frt.	0	640	0	720	0	640	0	600	0	200
6	10:10A	Wb. Frt.	340	40	300	0	440	0	760	0	160	0
7	10:55A	Eb. Pass.	0	560	0	560	0	640	0	660	0	240
8	11:25A	Wb. Pass.	160	320	0	200	0	440	80	480	0	40

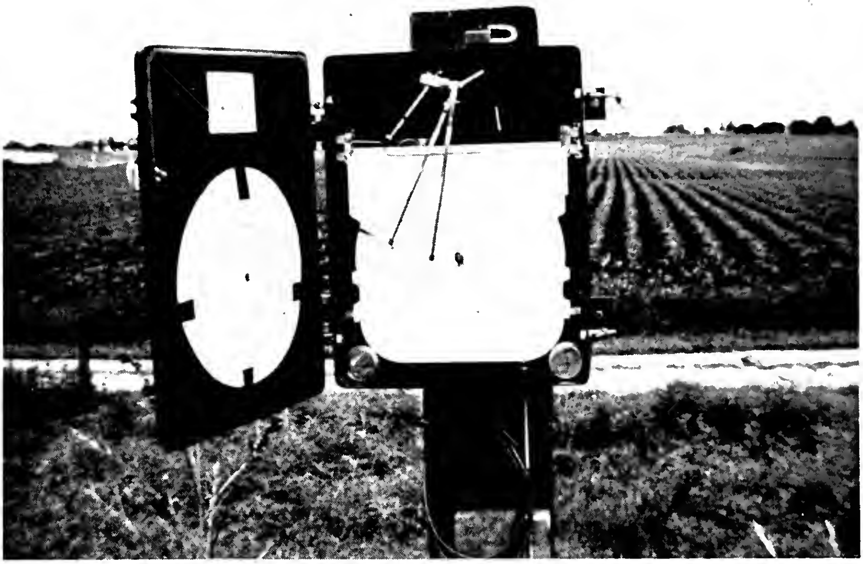


Fig. 13—Chart recorder installed to record rail temperature and rail joint gap.

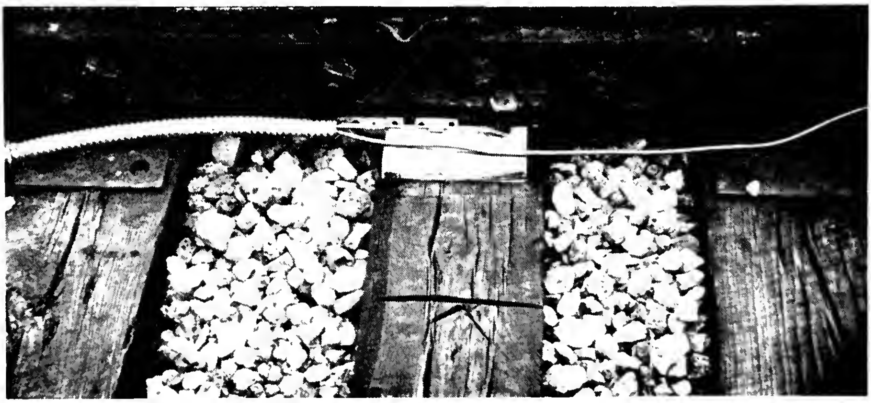


Fig. 14—Push-pull cable fastened to rail ends and temperature capillary tube leading to chart recorder.

The bolt tension was increased to 33,000 lb and the recorder operated another five weeks (Fig. 16). With the bolt tension at 33,000 lb the joint gap did not change through a rail temperature range of + 118° to + 40°. However, the recorder pen indicated some movement, which was found to be due to the expansion and contraction of the push-pull cable due to change in temperature. The recorder was then

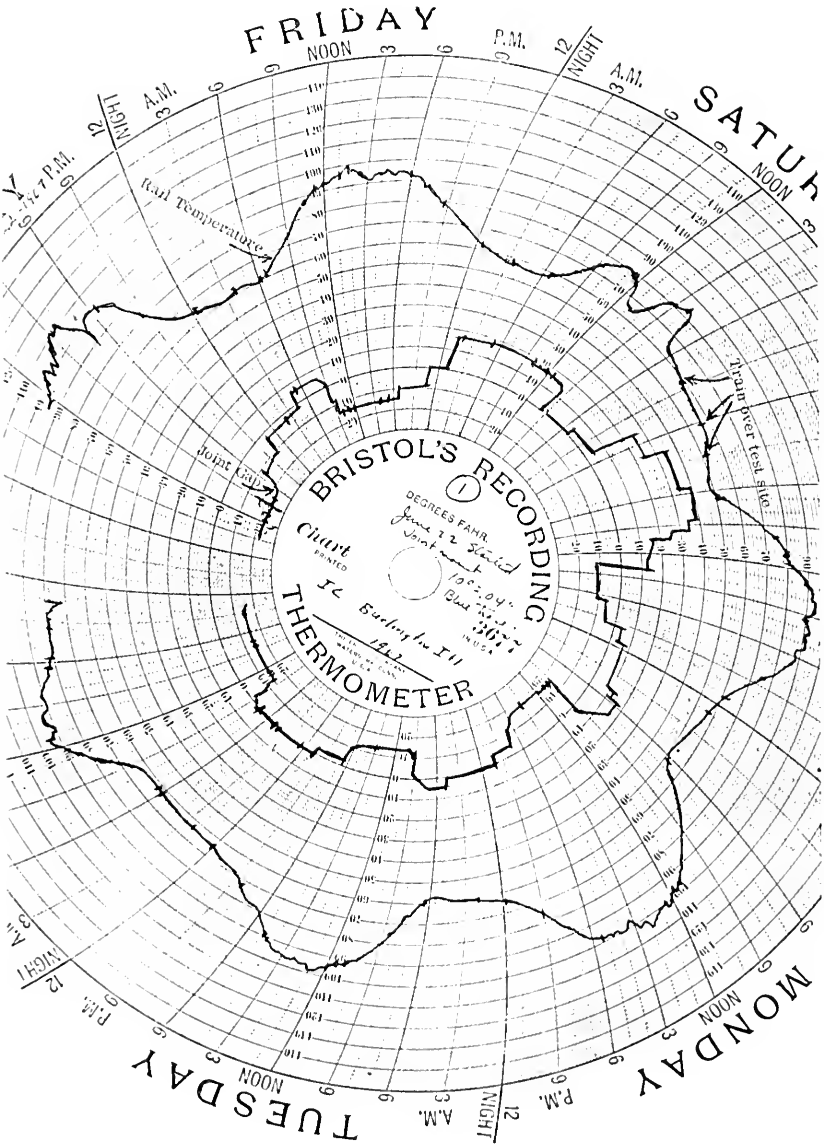


FIG. 15
RECORDER CHART SHOWING RAIL TEMPERATURE AND JOINT GAP MOVEMENT WITH 7000 LB BOLT TENSION

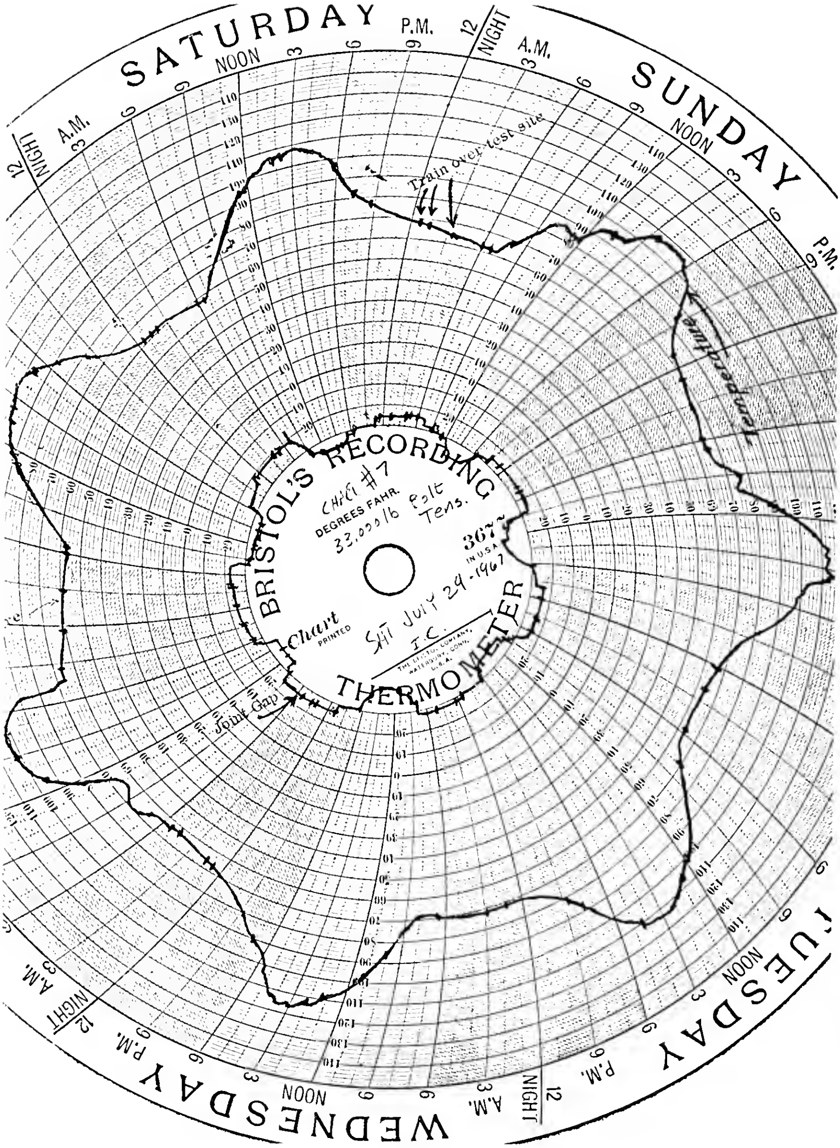


FIG. 16
RECORDER CHART SHOWING RAIL TEMPERATURE AND JOINT GAP MOVEMENT WITH 33,000 LB BOLT TENSION

brought to the Research Center and placed in the cold room to calibrate the joint gap device. While making this calibration through a range of — 30° to + 150°, it was found that the temperature recording device was not properly compensated at the low temperatures. The unit was returned to the factory and is expected to be back and reinstalled at the test site about the first of November.

Report on Assignment 6

Welding Secondhand Rail

W. E. Roberts (chairman, subcommittee), S. H. Barlow, J. D. Case, W. E. Chapman, L. S. Crane, B. J. Gordon, C. R. Harrell, B. J. Johnson, W. J. Jones, K. H. Kannowski, H. F. Longhelt, L. H. Martin, G. H. Maxwell, J. P. Morrissey, R. H. Patterson, M. S. Reid, R. P. Roden, V. R. Terrill, C. W. Wagner.

Your committee submits the following progress report on Inspection and Classification of Secondhand Rail for Welding. It is proposed to review this subject during 1968 and resubmit a report next year as Manual material.

INSPECTION AND CLASSIFICATION OF SECONDHAND RAIL FOR WELDING

A field inspection should be made while the rail is in service, and all rails containing severe engine driver burns, anchor nicks, excessive wear on the rail base or other visible flaws should be rejected for welding. It is recommended that a rail flaw detector car inspect the rail immediately preceding the rail recovery, with no more than 60 days maximum intervening.

Some railroads may choose to pick up rail out-of-face, while others may choose to pick it up in two or more phases. It is recommended that the rail selected for welding be picked up in such a manner that the rail wear pattern in the CWR string will remain approximately the same as it was in original service. One method to keep the rails in an orderly manner with respect to their wear patterns is to mark the north or west rail 2-4-6 etc., and the opposite rail 1-3-5 etc.

Some railroads remove jointed rail in quarter mile sections, then upon arrival at the welding plant the joint bars are removed. Joint bars, bolts and washers may be salvaged as repair material or the rail may be cropped without removing the joint bars. In the latter case, the two short pieces of rail, bars, bolts and washers are scrapped as a unit. The rail is carefully inspected after cropping, and rail not suitable for welding is removed. However, some engine driver burns are oxyacetylene welded to upgrade the rail.

When the rail arrives at the welding site, a qualified rail inspector should carefully inspect the rail for head wear, corrosion, base wear, sweeps, kinks or any other defect that may have escaped detection in the previous inspection. Rail for each CWR string must be matched to have the same height and width of head within $\frac{1}{16}$ in.

It is recommended that the rail be stored straight and level on a firm base and each tier stripped in four places.

The following restrictions are recommended:

1. Minimum rail length should be 27 ft after cropping.
2. Excess oils, grease, tars, etc., must be removed from the rail before welding.
3. Non-control-cooled and control-cooled rail should be welded separately.
4. Maximum head flow should be ¼ in on each side of the rail if shears are used to remove the upset metal.
5. Grade crossing rails must be free of corrosion or rejected for welding except for yards or similar tracks.
6. Bolt holes and bond holes must be eliminated by cropping.
7. After cropping, both ends of the rail should be inspected for piped condition.

Recommended Rail Grading Classifications

Rail Weight	Maximum Rail Wear-Inches Top	Maximum Rail Wear-Inches Gage	General Rail Use & Rail Condition
Class I			
140	1/4	1/2	Main Line use - Very minor engine burns and corrugation.
132-131	3/16	1/2	
122	5/32	7/16	
115	1/8	3/8	
112	1/8	1/4	
100	1/8	1/8	
90	1/8	1/8	
Class II			
140	3/8	3/4	Branch Lines - Small engine burns and corrugation.
132-131	5/16	3/4	
122	5/16	3/4	
115	5/16	3/4	
112	5/16	1/2	
100	3/16	1/4	
90	1/4	3/16	
Class III			
140	5/8	7/8	
132-131	7/16	7/8	
122	1/2	7/8	Light Branch Lines - Medium engine burns and corrugation, may be pitted and show some oxidation.
115	3/8	3/4	
112	3/8	3/4	
100	1/4	1/4	
90	5/16	5/16	
Class IV			
140	3/4	1	Yards.
132-131	9/16	1	
122	11/16	1	Any burns not mashed or fractured.
115	1/2	7/8	
112	1/2	7/8	
100	7/16	7/8	
90	3/8	3/8	

AREA Publications—Price List

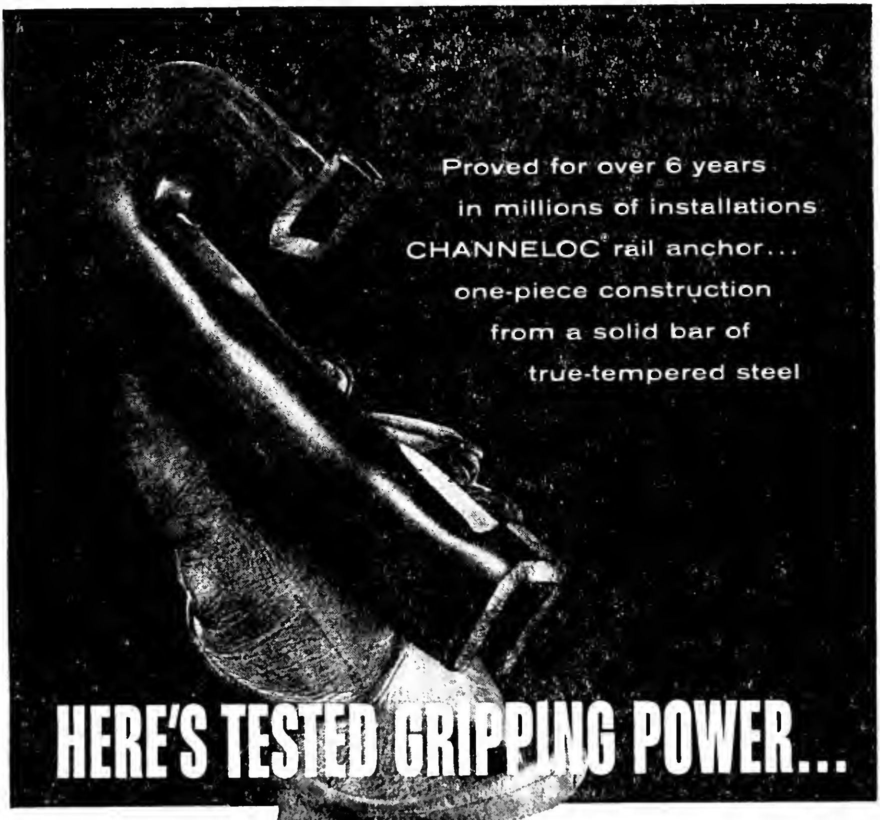
The following include some of the Association publications available from the secretary's office on order. Prices shown are for Members only:

	Member Price
Manual of Recommended Practice, complete in 2 volumes, including binders (first copy)	$18.00
Extra binders, each	5.00
Annual Supplements (first copy)	1.00

Separate Chapters

1—Roadway and Ballast	1.50
3—Ties	.25
4—Rail	.75
5—Track	.75
6—Buildings	1.50
7—Wood Bridges and Trestles	1.00
8—Masonry	1.00
9—Highways	0.50
11—Engineering and Valuation Records	1.25
13—Water, Oil and Sanitation Services	1.00
14—Yards and Terminals	1.00
15—Iron and Steel Structures	1.25
16—Economics of Railway Location and Operation	0.75
17—Wood Preservation	.50
18—Electricity (AAR Electrical Manual, $23.00 Complete with binder. Separate Sections available, prices on request)	
20—Contract Forms	1.25
22—Economics of Railway Labor	0.50
25—Waterways and Harbors	0.25
27—Maintenance of Way Work Equipment	0.50
28—Clearances	0.25
29—Waterproofing	0.25
Flexible-cover, loose-leaf binder for separate chapters, each	0.50

Portfolio of Trackwork Plans—119 plans, 8 sheets of specifications, 5 sheets definitions of terms, complete with leatherette cover	15.00
Federal Valuation of Railroads—87 pages, flexible cover	1.00
Instructions for Mixing and Placing Concrete—24 pages, flexible cover	0.40
Instructions for Care and Safe Operation of Welding and Grinding Equipment—23 pages, flexible cover	0.30
Specifications for Steel Railway Bridges (fixed spans)—70 pages, flexible cover	1.00
Specifications for Movable Railway Bridges—73 pages, punched sheets	1.00



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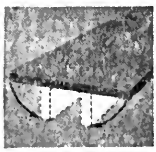

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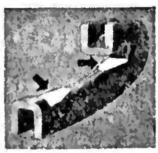

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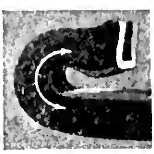

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Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen, and those designated by asterisks constitute the Engineering Division, AAR, Committee 4.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Revisions submitted for adoption were published in the Manual Recommendation Supplement to Bulletin 610, December 1967.

2. Collaborate with AISI Technical Committee on Rail and Joint Bars in research and other matters of mutual interest.
   Appendix 2a—Report on investigation of failures in control-cooled rail .... page 620

3. Rail Failure statistics, covering (a) all failures, (b) tranverse fissures, (c) performance of control-cooled rail.
   Progress report, presented as information .... page 632

4. Rail end batter; causes and remedies.
   Appendix 4a—Rail end build up service test installation, second progress report .... page 652

6. Joint bars: design, specifications, service tests, including insulated joints and compromise joints.
   No report.

7. Metallurgical effect of rail cropping methods.
   No report.

8. Causes of shelly spots and head checks in rail.
   Appendix 8a—Summary of heat-treated and alloy rail service test installations on curves with shelly histories—1967 .... page 664
   Appendix 8b—Shelly rail investigation—results of rolling-load tests at the AAR Research Center .... page 699

9. Standardization of rail sections.
   Progress report, presented as information .... page 708

THE COMMITTEE ON RAIL,
C. C. HERRICK, *Chairman*.

AREA Bulletin 612, February 1968.

Report on Assignment 2

Collaborate with AISI Technical Committee on Rail and Joint Bars in Research and Other Matters of Mutual Interest

C. C. HERRICK (chairman, subcommittee), J. B. CLARK, L. S. CRANE, W. J. CRUSE, D. T. FARIES, O. E. FORT, W. T. HAMMOND, T. B. HUTCHESON, A. B. MERRITT, JR., B. R. MEYERS, C. E. MORGAN, G. L. P. PLOW, H. M. WILLIAMSON.

Your committee presents, as Appendix 2, report on investigation of failures in control-cooled rail, prepared by M. J. Wisnowski, metallurgical engineer, Research Department, Association of American Railroads, under the direction of G. M. Magee, director of engineering research of that Department.

Appendix 2a

Investigation of Failures in Control-Cooled Rail

In the period between October 1, 1966 and October 1, 1967 there were seven failures in control-cooled rail, three service and four detected, investigated by the metallurgical laboratory of the Association of American Railroads Research Center. A summary of these service and detected failures can be found in Table 1. On completion of the metallurgical investigations a report was sent to the railroads submitting the failure and to the American Iron and Steel Institute, Technical Committee on Railroad Materials, to be forwarded to the manufacturer producing the rail.

Investigations 132-10A and B were conducted at the request of the Seaboard Air Line Railroad (now part of the Seaboard Coast Line Railroad) and involved two rail specimens both having a detected transverse discontinuity in the head.

These transverse discontinuities were detected by a detector car. Rail specimen 132-10A was identified as a 100-lb RE section rolled by the Bethlehem Steel Corporation's Steelton Mill in September 1945 from heat number 25478, rail letter G. To verify the presence of this defect, the rail specimen was nicked in the base and broken. This transverse discontinuity (transverse fissure) can be noted in a photograph of the fractured faces shown in Fig. 1. A longitudinal section was cut from the head of the rail in a horizontal plane and etched in a hot 50 percent aqueous solution of hydrochloric acid. This macro-etched section, Fig. 2, shows the presence of hot torn steel. This failure should be classified as a transverse fissure from hot torn steel.

Rail specimen 132-10B was identified as a 132-lb RE section rolled by the Bethlehem Steel Corporation's Steelton Mill in July 1949 from heat number 81429, rail letter E, ingot number 3. To verify the presence of the defect, the rail specimen was nicked in the base and broken. The transverse discontinuity (detail fracture) can be noted in a photograph of the fractured faces shown in Fig. 3. A microscopic examination was made on a specimen cut longitudinal to the rail in a vertical plane through the nucleus of this detailed fracture. Photomicrographs showing two different areas of the same shell can be seen in Figs. 4 and 5. It can be noted that an unidentifiable foreign material outlines this shelly crack. This failure should be classified as a detailed fracture from a shell.

Investigations 132-12A and B were conducted at the request of the Erie Lackawanna Railroad and involved two rail specimens both having a detected internal imperfection in the web. These internal imperfections were detected by a detector car and a hand test. Both rail specimens were identified as 132-lb RE sections rolled by the Bethlehem Steel Corporation's Lackawanna Mill in August 1965. Rail specimen 132-12A was rolled from heat number 400068, rail letter A, ingot number 26; rail specimen 132-12B was rolled from heat number 390078, rail letter A, ingot number 9. To verify the presence of the internal imperfections, these rails were cut through the point exhibiting this indication. Photographs of the cut cross sections showing the internal imperfection in the web can be seen in Figs. 6 and 8. A transverse section was cut from the ends of these specimens and etched in a hot 50 percent aqueous solution of hydrochloric acid. Photographs of the macro-etched transverse sections can be seen in Figs. 7 and 9. It can be noted that both these rails have a pipe, and a non-metallic entrapment (slag) commonly associated with pipe, in the web.

Investigation 135-16 was conducted at the request of the Great Northern Railway and involved a rail that failed in service. This rail was identified as a 112-lb RE section rolled by the CF&I Steel Corporation in April 1948 from heat number 7205, rail letter D, ingot number 20. A photograph of the fractured faces showing a fatigue ring development can be noted in Fig. 10. This fatigue ring development (detail fracture) started from a longitudinal separation close to the running surface of the rail head, then turned downward to form a transverse separation at a right angle to the running surface. A microscopic examination was made on a specimen cut longitudinal to the rail in a vertical plane through the nucleus of the separation. Photomicrographs showing two different areas of the same crack can be seen in Figs. 11 and 12. The presence of an unidentifiable foreign material outlining the crack can be noted in Fig. 11. The photomicrograph, Fig. 12, shows the presence of a gray (iron oxide) and white (unidentifiable) foreign material in this work-hardened metal. This failure should be classified as a detail fracture from a shell.

Investigation 135-28 was conducted at the request of the Chesapeake & Ohio Railway and involved a service failure that resulted from a derailment. This rail was identified as a 112-lb RE section rolled by the Bethlehem Steel Corporation's Lackawanna Mill in January 1947 from heat number 29055, ingot number 8. A photograph showing the gage side of this broken rail can be seen in Fig. 13. Photographs of the fractured faces at locations A and B in Fig. 13 can be seen in Figs. 14 and 15. A longitudinal section was cut from the rail end through the center of the head in a vertical plane and etched in a 10 percent nital solution. This etched section, Fig. 16, shows that the rail end was built up by welding. Hardness checks of the rail and weld (both deposit metal and work-hardened surface) are shown in this photograph. A photomicrograph showing the weld interface between the weld metal and rail can be seen in Fig. 17. The layer of ferrite noted at the weld interface can be attributed to carbon removal due to dilution. A metallurgical examination showed that this fractured rail was of sound steel quality. This failure was caused by an impact force of unusually high magnitude that is believed to have been the result of a derailment.

Investigation 135-29 was conducted at the request of the Canadian Pacific Railway and involved a rail that failed in service. This rail, selected as typical of 12 similar type rail failures that had occurred, was identified as a 115-lb RE section rolled by the Algoma Mill in March 1966 from heat number 14002, rail letter E, ingot number 8. A photograph of the rail base showing the bearing area between the base and tie plate can be seen in Fig. 18. Normally, the rail base bearing on the tie plate is concentrated at its edges and this is indicated by the light (polished) areas on each side of the base. This produces a stress condition in the base that may open a seam if one is present. Photomicrograph, Fig. 19, shows the seam that split and resulted in a rail failure. The ferrite (white area) outlining the seam is characteristic of this defect. This failure can be attributed to the presence of a base seam in conjunction with a high impact loading at subzero temperatures.

TABLE 1
SERVICE AND DETECTED FAILURES OF CONTROL-COOLED RAIL
OCTOBER 1, 1966 to OCTOBER 1, 1967

Lab. Failed Rail No.	Source of Failed Rail	Size of Rail	Producer (Mill)	Heat No. Rail Letter Ingot No.	Date Rolled	Type of Rail Failure	
						Service	Detected (Ver. by AAR)
132-10A	S.A.L.	100 lb RE	Beth. Steel Corp. Steelton Mill	25478-G	9-1945		T. F. from hot torn steel.
132-10B	S.A.L.	132 lb RE	Beth Steel Corp. Steelton Mill	81429-E- 3	7-1949		D. F. from a shell.
132-12A	Erie-Lack.	132 lb RE	Beth Steel Corp. Lack. Mill	400068-A-26	8-1965		Detected internal imperfection - pipe.
132-12B	Erie-Lack.	132 lb RE	Beth. Steel Corp. Lack. Mill	390078-A- 9	8-1965		Detected internal imperfection - pipe
135-16	G.N. R.R.	112 lb RE	C.F.&I. Co.	7205-D-20	4-1948	D. F. from a shell.	
135-28	C & O	112 lb RE	Beth. Steel Corp. Lack. Mill	29055- - 8	1-1947	Failure attributed to an impact force of unusually high magnitude.	
135-29	C.P. R.R.	115 lb RE	Algoma Mill	14002-E- 8	3-1966	Failure attributed to the presence of base seams.	

T. F. - Transverse Fissure
D. F. - Detailed Fracture

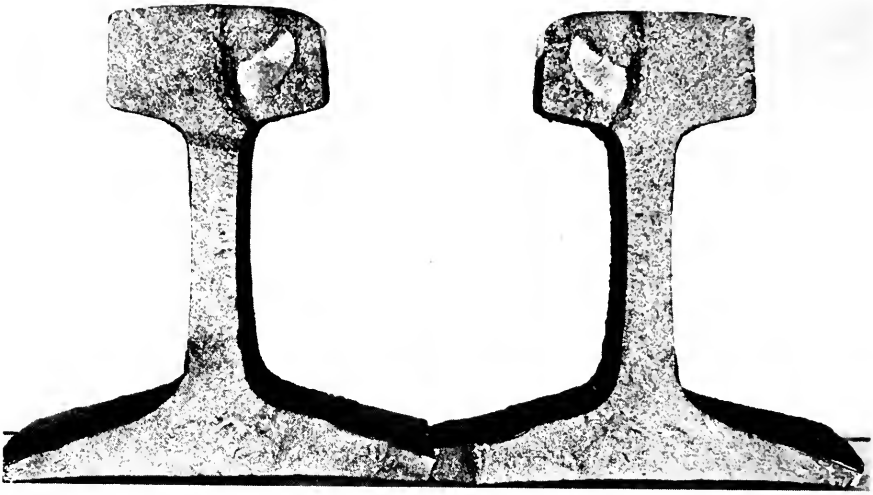

Fig. 1 (Investigation 132-10A)—Photograph showing the fractured faces resulting from nicking and breaking. The transverse discontinuity (transverse fissure) noted in this photograph was detected by a detector car.

Fig. 2 (Investigation 132-10A)—Photograph of a longitudinal section cut from the head in a horizontal plane. This macro-etched section shows the presence of hot torn steel. Etchant, hot 50 percent aqueous solution of hydrochloric acid.

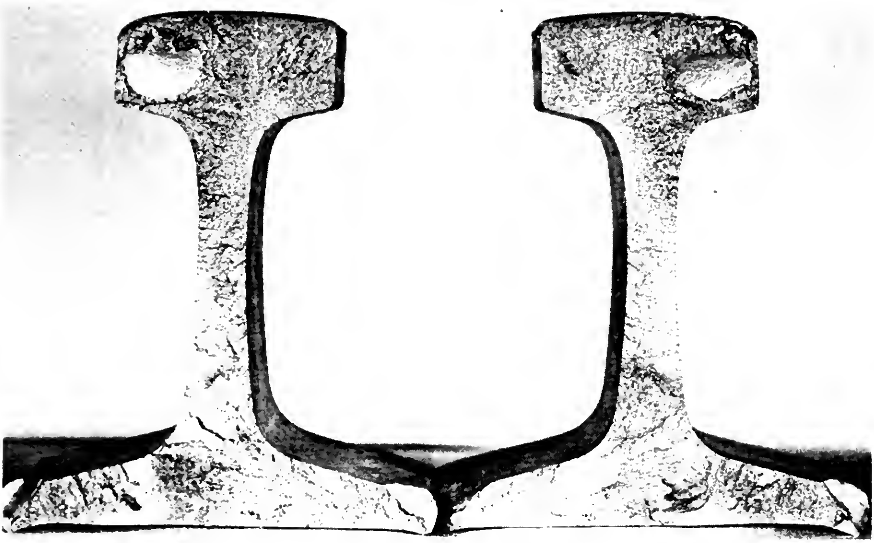

Fig. 3 (Investigation 132-10B)—Photograph showing the fractured faces resulting from nicking and breaking. The transverse discontinuity (detail fracture) noted in the photograph was detected by a detector car.

Fig. 4 (Investigation 132-10B)—Photomicrograph of a specimen cut longitudinal to the rail in a vertical plane through the nucleus (origin being a shell) of the detail fracture shown in Fig. 3. The presence of an unidentifiable foreign material outlining this shelly crack can be noted at a magnification of 250X. Etchant, 3 percent nital.

Fig. 5 (Investigation 132-10B)—Photomicrograph showing a different area of the same shelly crack shown in Fig. 4. Magnification, 250X. Etchant, 3 percent nital.

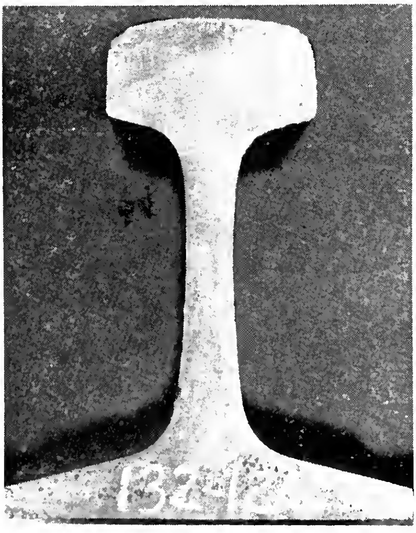

Fig. 6 (Investigation 132-12A)—Cross section of a rail that was cut through a point exhibiting an internal imperfection. This imperfection, detected by a Sperry detector car and hand test, can be noted in the web.

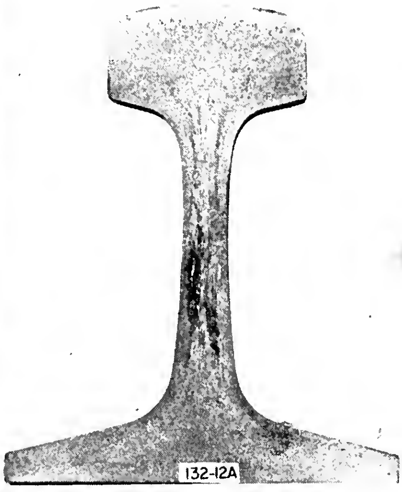

Fig. 7 (Investigation 132-12A)—Same cross section as in Fig. 6, after being macroetched in a hot 50 percent aqueous solution of hydrochloric acid. The presence of a pipe and a non-metallic entrapment (slag) commonly associated with a pipe can be noted in the web of this rail.

Fig. 8 (Investigation 132-12B)—Cross section of a rail that was cut through a point exhibiting an internal imperfection. This imperfection, detected by a Sperry detector car and hand test, can be noted in the web.

Fig. 9 (Investigation 132–12B)—Same cross section as in Fig. 8, after being macroetched in a hot 50 percent aqueous solution of hydrochloric acid. The presence of a pipe and a non-metallic entrapment (slag) commonly associated with pipe can be noted in the web of this rail.

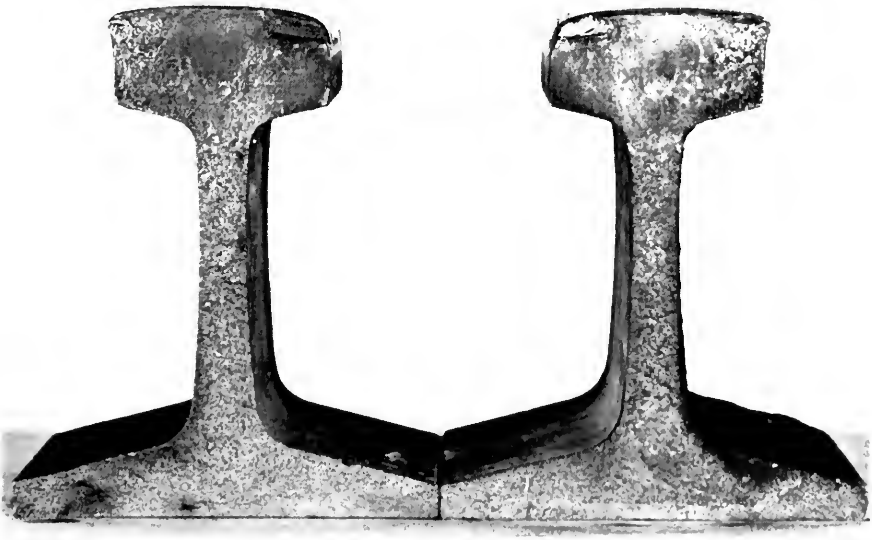

Fig. 10 (Investigation 135-16)—Photograph of the fractured faces showing a detail fracture from a shell. This detail fracture (fatigue ring development) started from a longitudinal separation close to the running surface of the rail head, then turned downward to form a transverse separation at a right angle to the running surface.

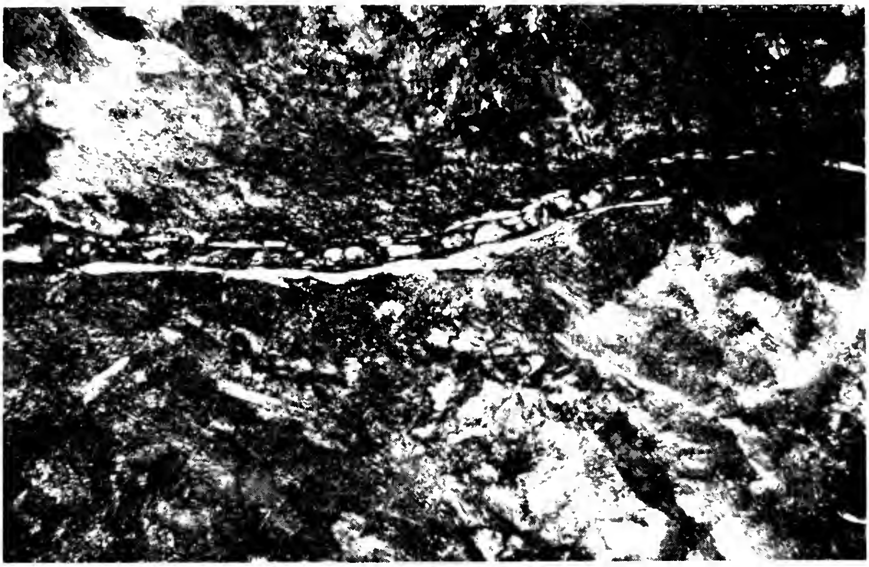

Fig. 11 (Investigation 135-16)—Photomicrograph of a specimen cut longitudinal to the rail in a vertical plane through the origin of the detail fracture shown in Fig. 10. The presence of an unidentifiable foreign material outlining this shelly crack can be noted at a magnification of 500X. Etchant, 3 percent nital.

Fig. 12 (Investigation 135-16)—Photomicrograph showing a different area of the same shelly crack shown in Fig. 10. It can be noted that a gray (iron oxide) and white (unidentifiable) foreign material are present in this work-hardened metal. Magnification, 500X. Etchant, 3 percent nital.

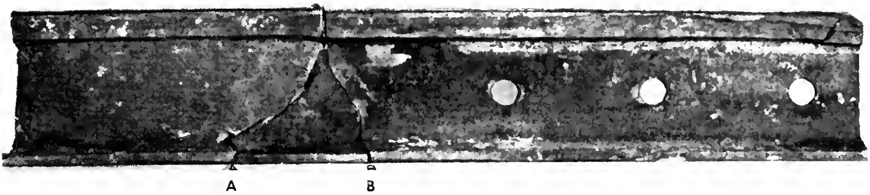

Fig. 13 (Investigation 135-28)—Photograph showing the gage side of a broken rail that was involved in a derailment.

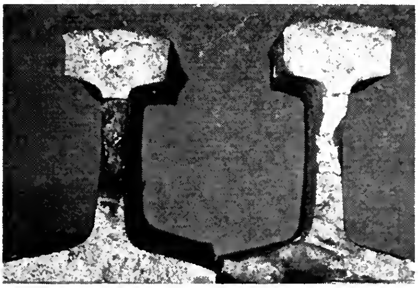

Fig. 14 (Investigation 135-28)—Photograph showing the fractured faces at location A in Fig. 13.

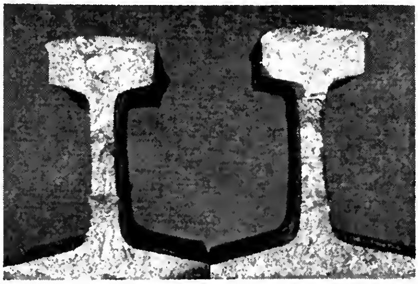

Fig. 15 (Investigation 135-28)—Photograph showing the fractured faces at location B in Fig. 13.

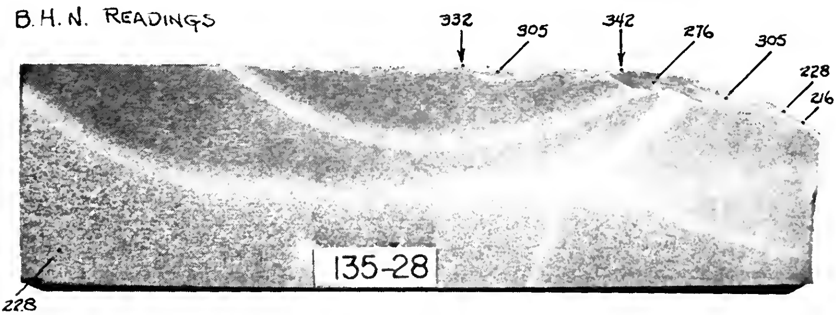

Fig. 16 (Investigation 135-28)—Longitudinal section cut from the rail end through the center of the head in a vertical plane and etched in a 10 percent nital solution. This etched section shows that the rail end was built up by welding. Hardness checks of the rail and weld (both deposit metal and work-hardened surface) are shown in the photograph.

Fig. 17 (Investigation 135-28)—Photomicrograph showing the weld interface between the weld metal and rail. A layer of ferrite (carbon removed as a result of dilution) can be noted at the weld interface. Etchant, 3 percent nital. Magnification, 50X.

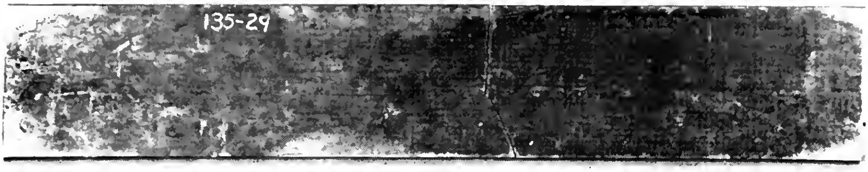

Fig. 18 (Investigation 135-29)—Photograph of the rail base showing the bearing area between the base and tie plate. The developed base seam is the result of an uneven bearing, indicated by the light (polished) areas on each side of the base.

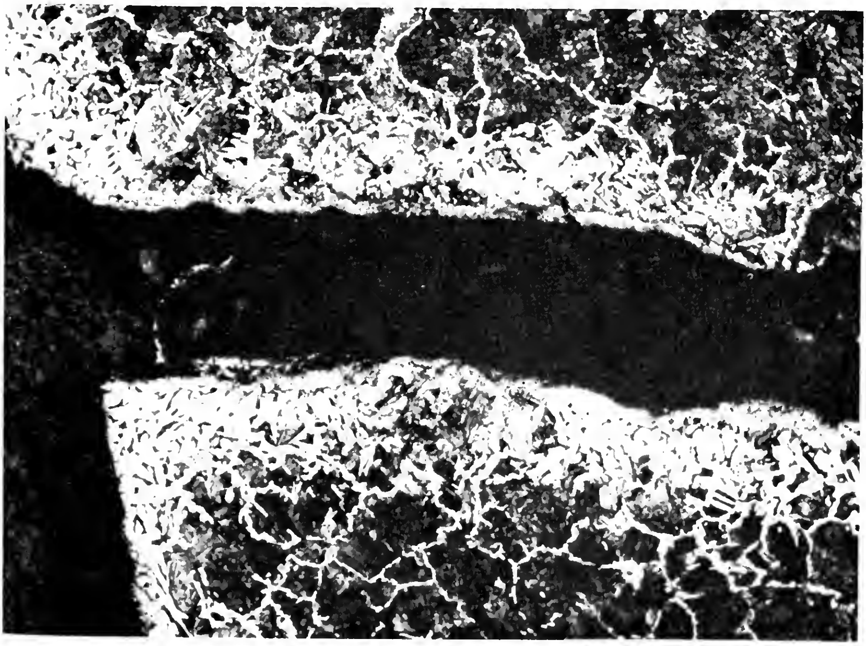

Fig. 19 (Investigation 135-29)—Photomicrograph showing the seam that split and resulted in a rail failure. The ferrite (white area) outlining the seam is characteristic of this defect. Etchant, 3 percent nital. Magnification, 100X.

Report on Assignment 3

Rail Failure Statistics Covering (a) All Failures, (b) Transverse Fissures, (c) Performance of Control-Cooled Rail

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These statistics are based on the rail failures reported to December 31, 1966, and are submitted as information. They include the service and detected failures reported by 47 railroads on all their main-track mileage, which constitutes approximately 90 percent of the main track of Class I railroads in the United States. This report is a technical service of the Association of American Railroads Research Department, W. M. Keller, vice president–research, and was prepared by M. J. Wisnowski, metallurgical engineer, under the direction of G. M. Magee, director of engineering research.

Although there have been some changes in the mileage reported upon due to various reasons as explained in the footnote to Table 1, nevertheless the amount of change is relatively small compared to the total mileage reported and does not, therefore, materially detract from the value of these statistics.

The accompanying tables and diagrams indicate the extent of control of the transverse fissure problem that has been obtained by the use of control-cooled rail and detector car testing, give data on the quality of each year's rollings for the various mills, and show the types of failures that are occurring on the various railroads as related to the mill producing the rail. Also included are data reported on all failures in rail of all ages and sections. Data on accumulated butt weld failures are included in the current report of Committee 31—Continuous Welded Rail, in this Bulletin.

Transverse Fissure Failures

Data on service transverse fissure failures and detected transverse defects are given in Table 1 and Fig. 1. Table 1 shows this information for individual roads for the 10-year period 1957 to 1966, incl. It can be noted that there was a slight increase in the total number of service failures for 1966 as compared with 1965, 424 failures compared to 405. A small increase in failures was reported by the Chicago, Milwaukee, St. Paul & Pacific (7 to 13), Chicago, Rock Island & Pacific (7 to 17), Great Northern (8 to 12), New York Central (9 to 15) and the New York, New Haven & Hartford (2 to 9). A substantial increase in failures was reported by the Louisville & Nashville (33 to 54), Pennsylvania (42 to 69) and the Southern Pacific (13 to 47). The Chicago & Eastern Illinois reported a reduction in service failures (12 to 5). Substantial reductions were shown by the Baltimore & Ohio (124 to 61), Erie Lackawanna (17 to 1) and the Missouri Pacific (33 to 10).

Railroads reporting increases in their 1966 detected failures outnumbered those reporting decreases, resulting in an overall increase in detected transverse defects. The total number of detected transverse defects increased from 26,066 in 1965 to

27,600 in 1966, a difference of 1,534. Substantial increases were reported by the Atchison, Topeka & Santa Fe (1376 to 1651); Baltimore & Ohio (858 to 2120); Chesapeake & Ohio (285 to 700); Chicago & Eastern Illinois (228 to 512); Chicago, Milwaukee, St. Paul & Pacific (589 to 858); Louisville & Nashville (1023 to 1373) and Southern Pacific (1274 to 1640). Substantial decreases were reported by the Chicago & North Western (1090 to 817); Erie Lackawanna (714 to 447); Missouri–Kansas–Texas (2246 to 1491); Norfolk & Western (3067 to 2514) and Union Pacific (2405 to 2090).

The number of track miles tested by detector cars according to data received from reporting roads increased from 215,932 in 1965 to 221,783 in 1966, as indicated in the following table:

Year Tested	*No. of Roads Reporting*	*Track Miles Tested by Detector Cars*
1957	57	212,082
1958	54	216,731
1959	53	212,833
1960	53	206,731
1961	48	193,516
1962	50	206,291
1963	46	199,401
1964	47	215,865
1965	45	215,932
1966	47	221,783

The complete story on service and detected failures is given in Fig. 1. The significance of this figure was explained in detail in a previous report which can be found in the AREA Proceedings, Vol. 61, page 845. Lines "C" and "D" were discontinued in 1958 because they had served their purpose. The most important line, "A" in Fig. 1, is for service tranverse fissures and shows the improvement that has been effected since 1943 by the use of control-cooled rail and detector car testing.

Mill Performance

The number of service and detected rail failures that occur during the first five years of service has been considered to be a good criterion of mill performance and the quality of rail as manufactured. Fig. 2 shows these failures for each year's rollings from 1908 to 1967, incl. An explanation of the large decrease in number of failures throughout this period was given in the November 1962 report, and can be found in the AREA Proceedings, Vol. 64, page 509. It is gratifying to note that the number of failures is continuing at the low level established in the 1955 rollings.

Fig. 3 shows the control-cooled rail failure rates cumulatively for the rollings from 1956 to 1965, incl., by the different mills. In making comparison between mills as reflected in this figure, it is important to recognize that because of service conditions on roads served by the various mills, these failure data should not be taken as necessarily indicative of the rail quality. A detailed explanation of the reasons for the difference in failure rates for the different mills and different year's rollings was given in the 1963 report for rollings up to and including the 1960 rollings. A comparison between this year's and last year's chart shows an increase in the 1964 failure rate (0.3 to 13.9) for rails rolled by the Algoma Mill. This increase can be attributed to the 82 failures reported under Other Head by the Canadian Pacific in 100-lb RE HF sections. These failures were of the crushed-head type, but there is some question as to whether these are due to mill defects. A metallurgical examination of typical failures will be made, and next year's report will show whether or not these are attributed to mill defects. The increase in Gary's 1958 failure rate (0.9 to 3.1) is due to error in the Norfolk & Western's reporting. Failures occurring in Gary's 1958 rollings were previously reported as Carnegie's E.T. 1958 rollings. The decrease in Lackawanna's 1964 failure rate (9.4 to 4.7) is due to the doubling in mile years with no additional failures. The relatively large 1965 Steelton failure rate (7.3) is attributed to 9 failures reported by the Baltimore & Ohio in 122-lb CB sections (1 CF & DF, 6 Web-in-Joint, 2 Web Other) and 2 failures reported by the Pennsylvania in 140-lb RE section (1 VSH and 1 Broken). Because of the small number of mile years in relation to the number of failures, this failure rate appears high.

Table 2 shows the tons of new rail rolled for the reporting roads by years. It will be noted that there was an increase in the 1965 rollings compared to those for the past seven years. The amount of 496,691 net tons does not represent all of the 1964 rollings for these roads because rollings for any railroad from one mill of less than 500 tons are not included.

Fig. 4 and Table 3 from which the figure is derived show not only the effect of years of service on rail failures, but also a comparison of the reduction in failure rates effected with the new rail sections introduced in 1947. In comparing this year's failures per 100 track miles against last year's failures, it can be noted that there was an increase in 1964 from 1.8 to 6.5. This increase can be attributed to the 82 failures (crushed heads) in 100-lb RE HF sections reported by the Canadian Pacific, which are subject to verification in next year's report, as previously explained.

Table 4 shows the total amount of track miles of rail (all sections in rollings between 1956 to 1965) segregated by mill and railroad. Also shown in this table is the total number of failures (excluding EBF's) and the engine burn failures that occurred on each railroad in 1966 in these rollings.

Types of Failures

Table 5 shows the accumulated service and detected failures per 100 track miles in the rollings from 1956 to 1965, incl., that have occurred to December 31, 1966, by types of failure and by mills. Compared to last year's data, the failures per 100 track miles for the CF and DF classification increased from 1.43 to 1.52, and increased for all types from 3.90 to 4.37. Web-in-Joint failures comprise 19.1 percent of all failures, Other Head 30.4 percent and CF and DF 34.9 percent. The Web-in-Joint type of failure is considered to be due to design or operating conditions rather than rail quality. Both the Other Head and CF and DF type of failures are believed to be associated with design, operating conditions and steel quality. The large number of CF's and DF's from Carnegie-E.T. rollings occurred on the Norfolk & Western due to heavy traffic and curvature and the large number from Colorado occurred on the Atchison, Topeka & Santa Fe, Denver & Rio Grande Western, Southern Pacific and Union Pacific for the same reasons. The large number of Web-in-Joint failures in the Algoma, Colorado, and Dominion rollings are evidently due to design as relatively few of this type of failure have been reported for the new sections shown in Table 5a.

The extent to which the "new rail sections" adopted in 1947 have affected the number of failures of each type is indicated in the following tabulation, which shows the accumulated failures in the "old sections" in the 1938 to 1947 rollings, incl., which were mostly control-cooled rail; in the 1956 to 1965 rollings, incl., which include mostly new but some of the old sections; and in the 1956 to 1965 rollings, incl., which include the new sections only as shown in Table 5a.

Accumulated Failures Per 100 Track Mile Years

	Old Sections (1938–1947)	*All Sections (1956–1965)*	*New Sections (1956–1965)*
TF—Verified	0.02	0.001	0.001
CF and DF	1.73	1.52	1.99
VSH	0.58	0.26	0.12
HSH	0.53	0.16	0.12
Other Head	0.52	1.33	0.72
Broken	0.75	0.14	0.08
Web-in-Joint	3.34	0.83	0.44
Web—Other	1.47	0.08	0.05
Base	0.30	0.04	0.02
ALL TYPES	9.24	4.37	3.53

Comparing the failure rates in the "new sections" with those in the "old sections," the following comments may be made:

TF—Since the old sections were mostly control-cooled rail also, the failures rates are low in both old and new sections.

CF & DF—This is one of the two classifications in which there has not been a substantial decrease in failure rates with the new sections. It was hoped that the change in the top contour of the rail at the gage corner would reduce the amount of shelling from which most of the CF's originate, but evidently the increase in wheel loads and train speeds has largely offset any benefit so effected.

VSH & HSH—The substantial reductions in these classifications are attributed to better manufacturing processes.

Other Head—The increase is attributed to mill quality and perhaps heavier wheel loads.

Broken—The reduction in this classification is probably due to a combination of increased rail size, better design, improved rail quality, and better maintenance practices for track and equipment.

Web-in-Joint, Web-Other—The very large reductions in these classifications are attributed to the new rail designs and new bolt hole spacing adopted in 1947.

Base—These failures are generally due to seams in the base, and improved rail quality and track maintenance are probably responsible for the reduction effected.

The volume of traffic has not changed enough between the two ten-year periods to have had much influence on the relative rates of rail failures.

With respect to the failures per 100 track mile years for each of the various new sections as shown in Table 5a the relatively high failure rate for the 133 PS is due to the large number of CF and DF's resulting from service conditions on the Union Pacific.

Table 6 shows the accumulated failures in the rollings from 1956 to 1965, incl., by mills, roads, and types of failure. The data shown in this table are particularly helpful in determining whether rail failures reported are due to mill quality or service conditions. It is interesting to note that 90 percent of the total failures have occurred on six railroads. The number of CF's and DF's on the Union Pacific has been greatly reduced over the number reported several years ago.

Table 7 shows the service and detected failures in the rail web within joint bar limits. Comparing these results with those reported last year, it will be noted that the number of joints reported inspected with defect-detecting instruments increased from 25,088,038 in 1965 to 42,106,014 in 1966. There was an 18 percent increase in the number of detected web failures from 22,193 in 1965 to 27,068 in 1966, and an increase in the number of service web failures from 13,175 in 1965 to 15,292 in 1966 or 14 percent. The total number of detected and service failures of this type reported in 1966 was 42,360. It is evident that the detection of web failures is an important part of the rail failure problem.

Professor R. E. Cramer at the University of Illinois examined rail failures submitted each year by the railroads which were thought to be transverse fissures until his retirement, October 1, 1963, and since then this work has been continued at the AAR Research Center. These are reported again in Table 8. Only one additional transverse fissure failure in control-cooled rail was reported in 1966. This failure was attributed to hot torn steel. It will be noted that no transverse fissure from a shatter crack or inclusion has been reported in rail rolled since 1951 nor a transverse fissure from hot torn steel in rail rolled since 1955. This shows that good quality control and mill practice has been followed in the manufacture of this rail.

Table 9 presents a sampling of welded engine burns and failures on a few railroads that have a record of these failures. The 21 failed welded engine burns during 1966 is an increase over the 15 reported during 1965. This number is relatively small compared to the 1,082,926 engine burns reported welded. From the number of roads involved these figures indicate the practice of welding engine burns is showing good service performance. This confirms the extensive laboratory tests made several years ago which indicated that although a welded engine burn was more likely to develop a failure than an unburned rail, it was less likely to develop a failure than an engine burn which had not been welded. The use of care and a good procedure in welding engine burns is, of course, an important factor in obtaining good service performance.

All Rail Failures

In 1961, the Rail Committee decided that it would be helpful to initiate a report of all rail failures in main track in order to determine whether the trend towards increasing wheel loads was resulting in an increase in total rail failures, and if so to what extent. Data were compiled for the year 1966 with respect to rail section, type of failure, service or detected, and track miles as reported on form 402B and are shown in Table 10. The number of track miles reported increased from 204,254.7 in 1965 to 214,600.0 in 1966. The total number of failures, including engine burn fractures, increased from 112,658 in 1965 to 122,588 in 1966. So far, as will be noted in the following tabulation, there does not seem to be any significant increase in the number of rail failures on a track-mile basis.

FAILURES PER TRACK MILE

Year	*All Sections*	*100 Lb and Less*
1962	0.52	0.68
1963	0.54	0.70
1964	0.65	0.80
1965	0.55	0.72
1966	0.57	0.73

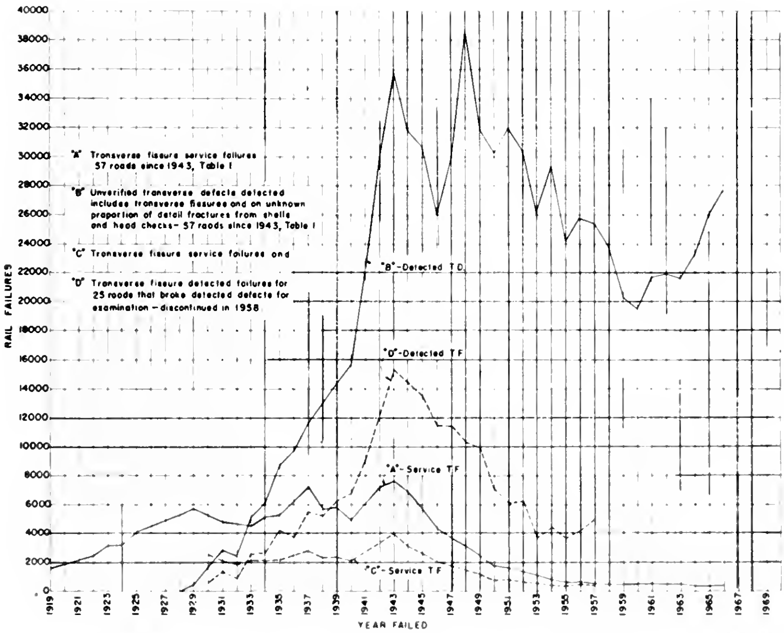

FIG I - ANNUAL SERVICE RAIL FAILURES DUE TO TRANSVERSE FISSURES AND TO DETECTED TRANSVERSE DEFECTS AS REPORTED BY ALL RAILROADS

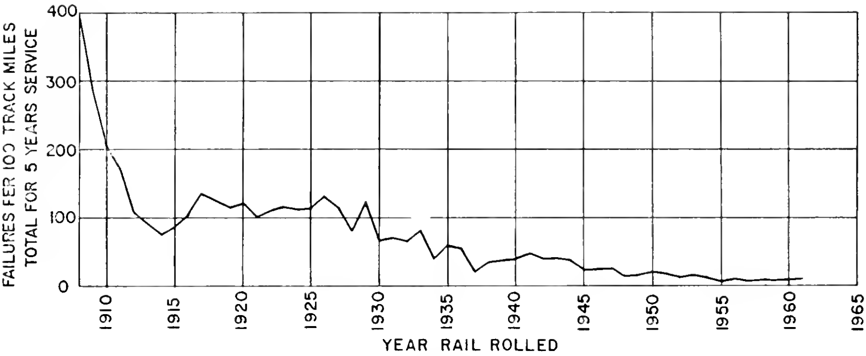

FIG. 2 - SERVICE AND DETECTED FAILURES IN UNITED STATES AND CANADA

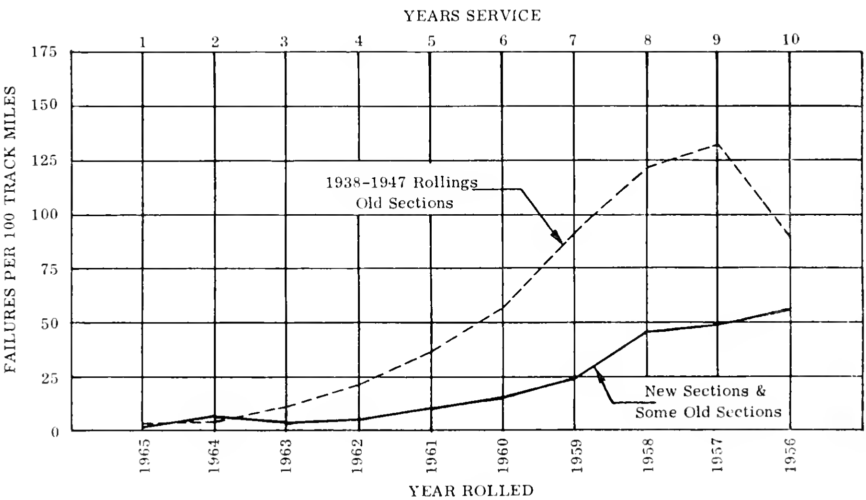

Fig. 4 - Control Cooled Rail Failures to December 31, 1966 Per 100 Track Miles - All Types Excluding Engine Burn Fractures - Service and Detected.

NOTE: Decline in failure rate in old sections occurred during 9th and 10th years of service due to rollings having a large number of failures being removed and no longer included in the reports.

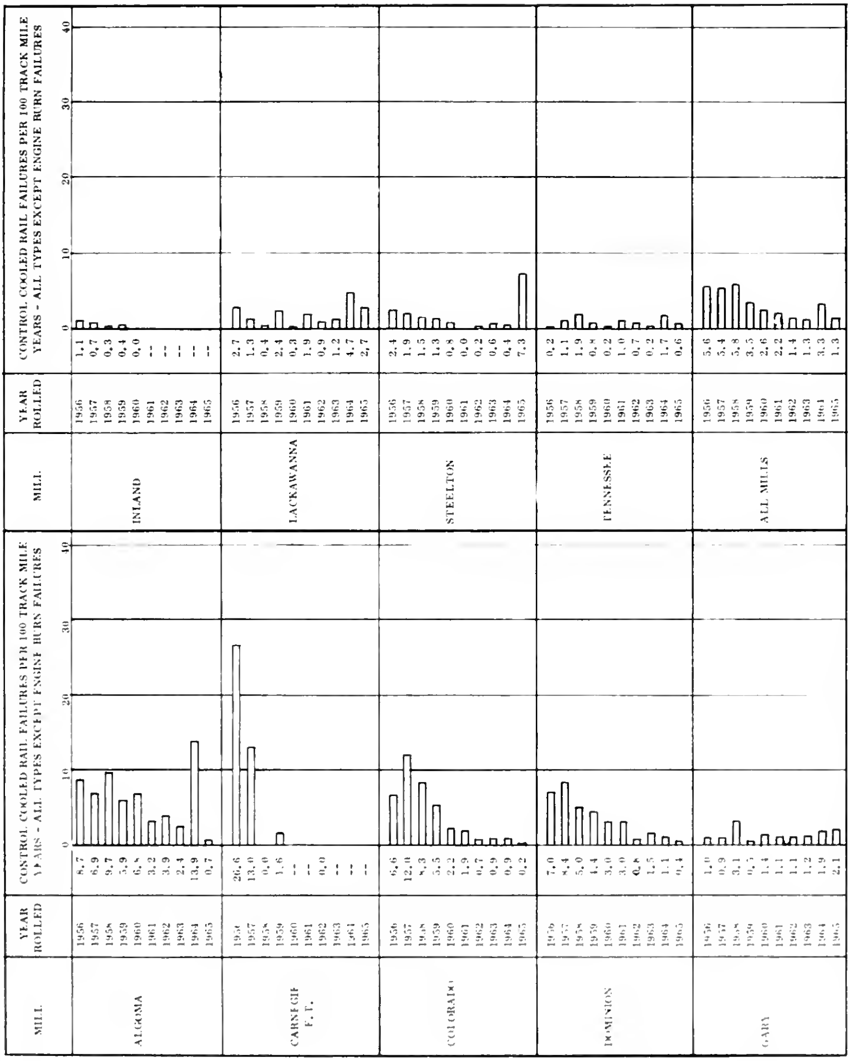

FIG. 3. CONTROL COOLED RAIL FAILURE RATES TO DECEMBER 31, 1966 BY MILLS - ALL TYPES EXCEPT ENGINE BURN FAILURES - SERVICE AND DETECTED

TABLE 1 - SERVICE FAILURES FROM TRANSVERSE FISSURES AND DETECTED FAILURES FROM TRANSVERSE DEFECTS BY RAILROADS AND BY YEAR FAILED - ALL ROLLINGS BY ALL PROCESSES

Service Failures

Year Failed	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	Total
AT&SF	7	9	7	12	18	6	6	13	18	19	115
ACL	2	5	6	9	5	6	4	1	7	7	52
B&O	150	102	95	101	59	78	98	57	124	61	925
B&OCT	6	9	6	6	3	0	--	0	--	--	30
Ban Aroos	0	0	0	1	0	0	0	1	0	0	2
B&LE	1	0	0	0	0	0	0	0	0	0	1
B&A	1	1	2	3	(a)	(a)	(a)	(a)	(a)	(a)	7
B&M	19	17	10	1	1	4	1	3	1	1	58
CN	--	--	--	--	--	--	--	0	0	0	0
CP	20	16	20	16	18	16	15	12	20	17	170
C. of Ga.	0	0	1	0	0	0	(b)	(b)	(b)	(b)	1
C&O (Sys.)	52	30	22	13	13	19	21	11	0	0	181
C&EI	1	0	0	0	0	10	29	23	12	5	80
C&NW	38	37	29	27	27	26	10	23	20	22	259
CB&Q	7	5	10	7	10	13	10	11	1	4	78
CI&L (Monon)	0	4	0	0	0	2	1	0	2	1	10
CMStP&P	11	16	12	6	5	10	3	6	7	13	89
CRI&P	13	8	8	13	3	9	9	8	7	17	95
C&S (c)	0	1	3	0	2	1	1	0	0	0	8
Cartier	--	--	--	--	--	0	0	0	0	0	0
D&H	0	0	0	0	0	1	0	0	0	0	1
D&RGW	0	5	0	0	0	0	0	0	0	0	5
Erie-Lack	3	10	9	13	5(d)	2(d)	9(d)	9(d)	17(d)	1(d)	78
FEC	0	0	0	0	0	(e)	(e)	(e)	(e)	(e)	0
GTW	1	8	2	0	0	0	0	0	0	0	11
GN	24	26	23	14	4	17	11	8	8	12	147
IC (Sys.)	5	6	6	5	4	8	8	9	1	0	52
JCL (NY&LB)	5	9	0	--	--	0	3	--	--	7	24
KCS	10	2	3	10	4	1	6	0	1	3	40
L&HR	0	0	0	0	0	0	0	0	0	0	0
L&NE	2	1	1	0	0	(f)	(f)	(f)	(f)	(f)	4
LV	8	3	2	3	1	3	1	2	0	0	23

Detected Failures

Year Failed	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	Total
AT&SF	1178	1423	917	1166	1249	1687	1147	1300	1376	1651	13094
ACL	648	565	603	590	428	547	625	672	401	473	5552
B&O	909	670	784	779	777	451	556	520	858	2120	8424
B&OCT	2	3	1	1	3	1	--	0	--	--	11
Ban Aroos	23	18	14	22	99	20	29	20	14	13	272
B&LE	45	13	31	11	7	32	25	11	18	9	202
B&A	41	22	12	20	(a)	(a)	(a)	(a)	(a)	(a)	95
B&M	250	50	154	122	253	320	148	138	112	167	1714
CN	--	--	--	--	--	--	-	1679	2205	2115	5999
CP	976	1210	1084	563	945	1246	836	768	725	779	9132
C. of Ga.	694	685	637	859	2027	1295	(b)	(b)	(b)	(b)	6197
C&O (Sys.)	200	497	346	194	236	368	391	287	285	700	3504
C&EI	253	154	181	190	219	124	300	272	228	512	2433
C&NW	675	838	1020	1037	988	938	787	792	1090	817	8982
CB&Q	825	293	277	381	261	223	394	445	406	476	3981
CI&L (Monon)	66	69	36	117	68	53	27	50	113	72	671
CMStP&P	864	749	668	679	576	649	438	687	589	858	6757
CRI&P	1076	228	239	339	329	256	326	333	321	245	3692
C&S (c)	124	114	117	98	78	87	72	99	98	166	1053
Cartier	--	--	--	--	--	0	0	0	0	4	4
D&H	121	180	123	65	69	310	165	72	101	165	1371
D&RGW	436	310	449	406	275	489	272	533	635	475	4230
Erie-Lack	275	180	161	272	668(d)	863(d)	1033(d)	943(d)	714(d)	447(d)	5556
FEC	87	61	77	27	28	(e)	(e)	(e)	(e)	(e)	280
GTW	99	117	77	118	181	114	147	113	106	142	1214
GN	1262	583	695	642	872	359	419	360	457	685	6334
IC (Sys.)	782	593	602	521	715	574	900	781	728	848	7044
JCL (NY&LB)	71	56	90	--	--	132	55	--	--	58	462
KCS	37	42	33	72	33	39	72	73	74	112	587
L&HR	3	4	5	0	11	2	7	1	3	1	37
L&NE	15	8	24	25	0	(f)	(f)	(f)	(f)	(f)	72
LV	72	57	69	32	39	52	74	53	39	36	523

TABLE 1 (Continued)

	Service Failures											Detected Failures										
Year Failed	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	Total	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	Total
LI	9	4	--	0	0	10	16	1	0	0	40	13	19	--	14	15	35	53	1	16	23	189
L&N	30	24	25	23	13	9	14	30	33	54	255	606	760	646	816	776	867	658	742	1023	1373	8267
Me. Cent.	5	1	1	3	3	0	1	1	2	3	20	43	45	28	4'	68	46	19	39	19	45	396
MStP&SStM	1	2	0	4	4	7	15	15	6	4	58	67	59	94	61	57	75	70	140	142	97	862
MKT	3	1	1	0	2	4	0	0	0	0	11	187	153	174	245	796	964	2146	1125	2246	1491	9527
MP Lines	11	16	9	18	15	18(g)	43(g)	43(g)	33(g)	10(g)	216	574	608	555	484	450	330(g)	473(g)	328(g)	515(g)	453(g)	4770
NC&StL	0	(h)	(h)	(h)	(h)	(h)	(h)	(h)	(h)	(h)	0	7	(h)	(h)	(h)	(h)	(h)	(h)	(h)	(h)	(h)	7
NYC (Sys.)	63	66	39(i)	28(i)	31(i)	64(i)	54(i)	41(i)	9(i)	15(i)	410	1152	841	584(i)	348(i)	392(i)	296(i)	1085(i)	1165(i)	1141(i)	1142(i)	8146
NYC&StL	1	7	1	6	--	--	--	(j)	(j)	(j)	21	32	11	56	33	--	--	--	(j)	(j)	(j)	132
NYNH&H	2	1	1	0	5	0	2	1	2	9	23	118	40	42	74	14	7	4	0	8	16	323
N&W	3	3	4	5	4	2	4	1	4(k)	8(k)	38	403	248	478	389	598	554	418	810	3067(k)	2514(k)	9479
NP	4	7	3	0	0	0	0	0	0	0	14	381	373	269	203	133	167	203	156	129	108	2122
PRR	95	51	46	48	61	51	35	44	42	69	542	1783	1810	1430	994	1382	1647	1532	1341	1145	1354	14418
P&LE	0	0	0	0	0	0	0	0	0	0	0	9	7	7	1	2	6	9	9	4	4	58
QNS&L	--	--	--	--	0	0	--	0	1	1	2	--	--	--	--	14	24	--	11	18	23	90
Reading	0	5	0	0	0	0	0	0	0	2	7	274	299	297	351	332	332	298	229	193	104	2709
RF&P	0	0	0	0	0	1	0	2	4	0	7	18	23	12	20	10	9	38	7	12	23	172
Rutland	4	2	3	2	2	(l)	(l)	(l)	(l)	(l)	13	0	0	0	0	0	(l)	(l)	(l)	(l)	(l)	0
StL-SF	3	1	4	0	0	0	0	0	0	0	8	1674	2145	287(m)	198	189	603	328	377	459	395	6655
SAL	10	17	15	19	8	14	22	2	5	9	121	259	257	230	317	249	221	243	211	242	204	2433
SP	23	13	20	23	167	19	42	22	13	47	419	833	623	368	289	782	925	2052	2166	1274	1640	10952
Southern	24	36	19	30	6	19	--	--	--	--	134	1263	1579	1225	1208	1584	1188	--	--	--	--	8047
T&NO	0	4	17	31	(n)	(n)	(n)	(n)	(n)	(n)	52	353	470	115	182	(n)	(n)	(n)	(n)	(n)	(n)	1120
T&P	5	4	2	5	--	(o)	(o)	(o)	(o)	(o)	16	49	35	77	60	--	(o)	(o)	(o)	(o)	(o)	221
UP	1	5	3	0	0	1	2	3	1	0	16	3113	3421	3640	3722	2517	2214	2155	3128	2105	2090	28405
Virginian	7	0	(p)	(p)	(p)	(p)	(p)	(p)	(p)	(p)	7	84	197	77(p)	(p)	(p)	(p)	(p)	(p)	(p)	(p)	358
W. Md.	0	0	0	1	3	1	1	0	4	3	13	35	33	86	59	37	203	525	269	312	355	1914
ALL ROADS	693	600	493	506	506	482	497	403	405	124	5009	25439	23848	20303	19460	21831	21894	21554	23256	26066	27600	231251

-- No report received
(a) Incorporated with the New York Central
(b) Merged with Southern R. R.
(c) Includes the FW&Denver Failures
(d) Merged with the DL&W R. R. forming the Erie-Lackawanna R. R. Co.
(e) FFC did not report because of a strike by the non-operating employees
(f) L&NE did not report because of bankruptcy November 1, 1961
(g) Merged with the T&P R. R.
(h) Merged with the L&N R. R.
(i) Includes B&A, NYC Southern District (CCC&STL, P&E), NYC (New York District); NYC (Eastern District); NYC (Western District) and NYC (Northern District)
(j) Merged with the N&W R. R.
(k) Includes NYC&StL and Wabash Railroad
(l) Rutland R. R. closed down by strike during entire year 1963. Ceased operations 12-31-64
(m) Includes engine burn fractures
(n) Merged with the SP Co. to become Southern Pacific Co., Texas and Louisiana Lines
(o) Merged with the MP R. R.
(p) Merged with the N&W R. R.

TABLE 2
TONS OF RAILS AND TRACK MILES OF EACH YEAR'S ROLLINGS 1956 - 1965, INCL.
REPORTED BY 45 RAILROADS

Year Rolled	OH CONTROL COOLED ONLY	
	NET TONS	TRACK MILES
1956	865,017	4,024.40
1957	814,723	3,480.30
1958	401,532	1,855.90
1959	458,260	2,131.10
1960	364,097	1,674.60
1961	290,210	1,339.50
1962	273,944	1,252.60
1963	408,904	1,876.90
1964	450,081	2,167.90
1965	496,691	2,303.00
TOTAL	4,823,459	22,106.20

TABLE 3
SERVICE AND DETECTED FAILURES OF ALL TYPES EXCEPT ENGINE BURN FAILURES
ACCUMULATED FROM DATE ROLLED TO DECEMBER 31, 1966, PER 100 AVERAGE
TRACK MILES, CONTROL COOLED RAIL ONLY, IN ALL ROLLINGS FROM ALL MILLS

Year Rolled	YEARS OF SERVICE									
	1	2	3	4	5	6	7	8	9	10
1956	0.4	1.3	3.3	6.3	10.1	15.0	21.7	26.4	42.9	56.1
1957	0.5	1.3	2.5	4.3	7.4	13.1	21.5	33.4	48.6	
1958	1.0	1.8	3.0	5.2	9.3	19.4	30.6	46.0		
1959	2.0	2.8	4.3	7.2	9.8	16.3	24.5			
1960	0.5	1.6	3.0	4.7	9.6	15.6				
1961	0.8	2.0	2.0	5.9	10.6					
1962	0.6	1.0	3.1	5.5						
1963	0.4	1.8	3.8							
1964	1.5	6.5								
1965	1.3									

TABLE 4 - TRACK MILES AND 1966 FAILURES, ALL TYPES, IN ROLLINGS 1956 TO 1965, INCL.
OPEN-HEARTH CONTROL-COOLED RAIL ONLY

	TRACK MILES BY MILL										1966 FAILURES	
ROAD	ALG	CARN	COLO	DOM	GARY	INLD	LACKA	STLTN	TENN	TOTAL	EBFs EXCL.	EBFs ONLY
AT&SF			1165		706	21				1892	115	
ACL								10	298	308	1	
B&O		98			375		163	248		824	21	
Ban Aroos								13		13		
B&LE		7			22					29	1	
B&M								11		11		
CN	2422			3491	99	10	171	5		6198	662	117
CP	2172			553			4			2729	530	
CARTIER				38	152					190	10	
C&O Sys.		4			482	221	176	144		1030	35	
C&EI					44					44		
C&NW					224	57	16			297		1
CB&Q			317		267	15				599	1	
CI&L					22	7				29		
CMStP&P					326	44				370	1	
CRI&P			146		240	35				121	3	1
C&S			96							96		
D&H							10	29		39	1	
D&RGW			196							196	9	
Erie-Lack		4			111		20	6		141	1	
GTW					99	6				105	2	5
GN			301		294	43	125	30		793	49	
IC Sys.					358	101			262	721		
JCL								17		17		
KCS					50					50	1	
LV							60			60		
L&N									779	779	32	2
Me. Cent.							18	3		21		
MStP&SStM	15				63	107	10			195	4	
MKT			13		11	8			5	37		
MP Lines			329		340			14	322	1005	4	
NYC Sys.					168		294			462	19	2
NYNH&H		7						38		45	1	
N&W		204			129		5	97		435	230	3
NP			333		339	25	97			794	12	1
PRR		69			177			287		533	6	
P&LE		25			46					71	1	
QNS&L				58						58	2	
Reading								103		103		
RF&P								30		30		
STLSF					11				440	451	1	
SAL									541	541	1	
SP Co. Sys.			1316						60	1376	321	19
UP			819		341	17				1177	189	1
W. Md.		29						132		161		
TOTAL	4609	387	5031	4140	5496	720	1169	1217	2707	25476	2296	155

NOTE The following railroads did not report and were omitted from this table: FEC, N&W - Lake Region (Previously NYC&STL RR), N&W - Western Region (Previously Wabash RR), and Southern - No Reason. L&NE - Because of Bankruptcy.
The NYC Sys. includes the B&A, NYC Southern District (CCC&STL, P&E), NYC (New York District), NYC (Eastern District) NYC (Western District) and NYC (Northern District).
The DL&W merged with the Erie Railroad.
The NC&STL merged with the L&N Railroad
The T&NO merged with the SP Railroad.
The Virginian merged with the N&W Railroad.
The T&P merged with the MP Railroad
NYC&STL merged with the N&W Railroad.

TABLE 5 - ACCUMULATED FAILURES AND FAILURES PER 100 TRACK MILES, IN ROLLING 1956 TO 1965, INCLUSIVE, FROM DATE ROLLED TO DECEMBER 31, 1966, SERVICE AND DETECTED, BY MILL AND TYPE OF FAILURE

OH CONTROL-COOLED RAIL ONLY

	ACCUMULATED FAILURES TO DECEMBER 31, 1966 (EXCL. EBFs)												
							WEB						
MILL	TF VER AAR	CF & DF	VSH	HSH	OTHER HEAD	BROKEN	IN JT.	OTHER	BASE	ALL TYPES	TRACK MILES	TRACK MILE YEARS	FAILURES PER 100 TRACK MI. YEARS
ALGOMA		40	264	96	1,161	39	412	38	28	2,078	4,647	29,104	7.14
CARNEGIE (ET)	1	718	3	10	10	1	18	1		762	436	3,863	19.73
COLORADO		1,329	37	88	149	19	285	25	5	1,937	5,243	30,768	6.30
DOMINION		10	48	33	670	88	352	23	26	1,250	4,117	24,489	5.10
GARY		182	13	11	36	45	111	22	2	422	5,524	33,223	1.27
INLAND		18	4	3	5	5	13	3	3	54	719	6,588	0.82
LACKAWANNA		12	5	3	24	8	58	5	5	120	1,169	6,964	1.72
STEELTON		80	7	7	3	5	18	2		122	1,255	7,398	1.65
TENNESSEE		7	29	3	33	3	42	5	1	123	2,841	14,926	0.82
ALL MILLS	1	2,396	410	254	2,091	213	1,309	124	70	6,868	25,951	157,323	4.37
FAILURES PER 100 TRACK MILE YEARS	0.001	1.52	0.26	0.16	1.33	0.14	0.83	0.08	0.04	4.37			

Definition of symbols:

TF - Transverse Fissure
CF - Compound Fissure
DF - Detail Fracture
VSH - Vertical Split Head
HSH - Horizontal Split Head
EBF - Engine Burn Fracture

TABLE 5a - ACCUMULATED FAILURES AND FAILURES PER 100 TRACK MILES, IN ROLLINGS 1956 TO 1965, INCLUSIVE, FROM DATE ROLLED TO DECEMBER 31, 1966, SERVICE AND DETECTED, BY RAIL SECTION AND TYPE OF FAILURE

OH CONTROL-COOLED RAIL ONLY

RAIL SECTION	ACCUMULATED FAILURES TO DECEMBER 31, 1966 (EXCL. EBFs)									ALL TYPES	TRACK MILES	TRACK MILE YEARS	FAILURES PER 100 TRACK MI. YEARS
	TF VER AAR	CF & DF	VSH	HSH	OTHER HEAD	BROKEN	WEB IN JT.	WEB OTHER	BASE				
106 CF&I		1	2		3	1	2			9	30	257	3.50
112 TR			1						1	2	106	3,565	0.06
115 RE		72	14	26	530	34	45	15	11	777	6,291	39,556	1.96
119 CF&I		260	4	10	16	6	41	7	2	346	2,583	14,294	2.42
127 NYC (Mod)		5	3	1	2		48			59	208	1,832	3.22
129 TR										0	74	515	0.00
132 RE		917	51	30	172	32	105	17	3	1,327	4,975	32,481	4.09
133 PS		796	1	32	66	7	39	1	1	943	1,251	7,081	13.32
136 RE		258	23	46	42	6	197	19	1	592	1,771	8,748	6.77
136 NYC		1	1				20	1		23	306	1,126	2.04
140 RE	1	4	2		2	5	10			24	979	6,106	0.39
155 PS			3		1					4	59	806	0.50
TOTAL	1	2,314	135	145	834	91	507	60	19	4,106	18,933	116,367	3.53
TOTAL PER 100 TRACK MILE YEARS	0.001	1.99	0.12	0.12	0.72	0.08	0.44	0.05	0.02	3.53			

TABLE 6
ACCUMULATED FAILURES OF ALL TYPES FOR OH CONTROL-COOLED RAIL, ONLY IN ROLLING 1956 - 1965, INCL., ACCUMULATED TO DECEMBER 31, 1966, SERVICE AND DETECTED, SEGREGATED BY ROADS AND MILLS

ROADS	TF Ver AAR	CF & DF	VSH	HSH	Other Head	Broken	Web			FAILURE TOTALS			
										EBFs Excl.		EBFs Only	
							In Jt.	Other	Base	Accum. Total	1966	Accum. Total	1966
ALGOMA													
CN	0	1	46	15	498	31	29	18	8	646	189	85	33
CP	0	39	218	81	661	8	383	20	18	1428	478	9	0
MStP&SStM	0	0	0	0	2	0	0	0	2	4	2	0	0
TOTAL	0	40	264	96	1161	39	412	38	28	2078	669	94	33
CARNEGIE													
B&O	0	0	1	0	0	0	0	0	0	1	0	0	0
Erie-Lack	0	0	0	0	0	0	1	0	0	1	0	0	0
NYNH&H	1	0	0	0	0	0	0	0	0	1	0	0	0
N&W	0	715	2	10	10	0	5	1	0	743	178	10	3
PRR	0	0	0	0	0	1	4	0	0	5	1	0	0
P&LE	0	2	0	0	0	0	2	0	0	4	1	0	0
W. Md.	0	1	0	0	0	0	6	0	0	7	0	0	0
TOTAL	1	718	3	10	10	1	18	1	0	762	180	10	3
COLORADO .													
AT&SF	0	172	2	4	11	2	12	4	2	209	107	0	0
CRI&P	0	0	0	0	2	1	0	0	0	3	1	2	0
C&S	0	0	1	0	0	0	0	0	0	1	0	5	0
D&RGW	0	11	3	1	5	2	7	0	0	29	9	0	0
GN	0	50	0	1	17	0	0	0	0	68	40	1	0
NP	0	18	8	1	2	1	8	0	1	39	11	4	1
SP Co. Sys.	0	353	23	52	60	12	234	20	1	755	317	33	19
UP	0	725	0	29	52	1	24	1	1	833	160	2	2
TOTAL	0	1329	37	88	149	19	285	25	5	1937	645	47	22
DOMINION													
CN	0	0	41	24	653	85	178	22	23	1026	468	199	79
CP	0	5	5	3	15	2	173	1	3	207	51	0	0
CARTIER	0	3	0	0	1	0	0	0	0	4	4	0	0
QNS&L	0	2	2	6	1	1	1	0	0	13	2	0	0
TOTAL	0	10	48	33	670	88	352	23	26	1250	525	199	79
GARY													
AT&SF	0	7	0	0	2	0	8	3	0	20	8	0	0
B&O	0	1	1	1	3	4	15	3	0	28	10	0	0
B&LE	0	0	0	0	0	2	0	0	0	2	1	0	0
CN	0	0	0	0	0	0	1	0	0	1	1	5	5
CARTIER	0	1	0	2	2	14	1	7	0	27	6	0	0
C&O Sys.	0	12	1	1	2	10	27	4	0	57	26	0	0
C&NW	0	0	0	0	0	0	2	0	0	2	0	0	0
CB&Q	0	0	0	0	0	0	0	0	1	1	1	0	0
CMStP&P	0	0	5	4	4	2	0	2	0	17	1	0	0
CRI&P	0	1	2	0	0	0	3	0	0	6	2	1	1
Erie-Lack	0	0	0	0	0	0	2	0	0	2	1	2	0
GTW	0	0	0	0	1	3	1	0	0	5	2	5	5
GN	0	5	0	0	1	0	1	0	1	8	4	0	0
IC Sys.	0	0	0	0	1	2	3	0	0	6	0	0	0
KCS	0	0	1	0	0	0	0	0	0	1	1	0	0
MP Lines	0	0	0	0	0	1	1	1	0	3	2	2	0
NYC Sys.	0	5	1	0	0	0	29	1	0	36	19	2	2
N&W	0	92	0	0	0	0	1	0	0	93	29	0	0
NP	0	0	1	0	6	2	5	1	0	15	0	0	0
PRR	0	1	0	0	1	4	3	0	0	9	2	0	0
P&LE	0	0	0	0	0	1	0	0	0	1	0	0	0
UP	0	57	1	3	13	0	8	0	0	82	24	2	0
TOTAL	0	182	13	11	36	45	111	22	2	422	140	19	15

TABLE 6 - CONTINUED

ROADS	TF Ver AAR	CF & DF	VSH	HSH	Other Head	Broken	Web: In Jt.	Web: Other	Base	FAILURE TOTALS: EBFs Excl. Accum. Total	EBFs Excl. 1966	EBFs Only Accum. Total	EBFs Only 1966
INLAND													
AT&SF	0	0	1	0	0	0	0	0	0	1	0	0	0
C&O Sys.	0	2	1	1	0	0	6	1	0	11	5	0	0
C&NW	0	0	0	0	0	0	2	1	0	3	0	0	0
CMStP&P	0	0	1	0	0	0	1	0	1	3	0	0	0
CRI&P	0	0	0	0	0	0	0	0	0	0	0	2	0
GTW	0	0	0	0	1	0	0	0	0	1	0	0	0
GN	0	2	1	0	0	0	0	0	0	3	1	0	0
IC Sys.	0	0	0	2	1	1	1	1	0	6	0	0	0
MStP&SStM	0	0	0	0	0	4	2	0	2	8	2	0	0
NP	0	0	0	0	2	0	0	0	0	2	0	0	0
UP	0	14	0	0	1	0	1	0	0	16	5	0	0
TOTAL	0	18	4	3	5	5	13	3	3	54	13	2	0
LACKAWANNA													
B&O	0	0	0	2	1	3	6	3	0	15	2	0	0
CN	0	0	1	0	1	4	1	1	3	11	4	0	0
CP	0	0	1	0	1	0	3	0	1	6	1	0	0
C&O Sys.	0	1	0	0	1	0	3	1	0	6	1	0	0
C&NW	0	0	0	0	0	0	0	0	0	0	0	1	1
Erie-Lack	0	0	1	0	0	1	1	0	0	3	0	0	0
GN	0	8	0	0	17	0	1	0	0	26	3	1	0
LV	0	0	0	0	0	0	3	0	0	3	0	2	0
Me. Cent.	0	0	0	0	1	0	0	0	0	1	0	0	0
NYC Sys.	0	1	2	1	2	0	39	0	0	45	30	3	0
N&W	0	2	0	0	0	0	0	0	0	2	2	0	0
NP	0	0	0	0	0	0	1	0	1	2	1	0	0
TOTAL	0	12	5	3	24	8	58	5	5	120	44	7	1
STEELTON													
B&O	0	1	1	0	0	0	6	2	0	10	9	0	0
C&O Sys.	0	0	0	1	0	0	3	0	0	4	3	0	0
D&H	0	2	0	0	0	0	0	0	0	2	1	0	0
Erie-Lack	0	0	0	0	0	0	1	0	0	1	0	0	0
GN	0	0	1	2	0	0	0	0	0	3	1	0	0
Me. Cent.	0	0	0	0	0	0	1	0	0	1	0	0	0
NYNH&H	0	0	0	0	0	0	1	0	0	1	1	0	0
N&W	0	77	1	4	2	0	4	0	0	88	21	0	0
PRR	0	0	1	0	1	4	1	0	0	10	3	2	0
W. Md.	0	0	0	0	0	1	1	0	0	2	0	0	0
TOTAL	0	80	7	7	3	5	18	2	0	122	39	2	0
TENNESSEE													
ACL	0	0	2	0	15	0	1	0	0	18	1	0	0
IC Sys.	0	0	1	0	1	0	0	0	0	2	0	0	0
L&N	0	2	22	0	15	1	32	3	1	76	32	1	2
MP Lines	0	0	0	0	0	0	2	0	0	2	2	0	0
STL&SF	0	0	0	0	1	0	0	0	0	1	1	0	0
SAL	0	1	2	1	1	2	1	0	0	8	1	0	0
SP Co. Sys.	0	4	2	2	0	0	6	2	0	16	4	0	0
TOTAL	0	7	29	3	33	3	42	5	1	123	11	4	2
ALL MILLS	1	2396	410	254	2091	213	1309	124	70	6868	2296	384	155

TABLE 7
RAIL FAILURES IN THE WEB WITHIN THE JOINT BAR LIMITS FOUND IN 1966
ON RAIL OF 100 LB AND ALL HEAVIER SECTIONS

Railroad	Rail Rolled Previous to 1937				Rail Rolled in 1937 and After				Joints Inspected with Defect Detecting Instruments
	Detected Failures		Service Failures		Detected Failures		Service Failures		
	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other	
AT&SF	71	61	21	13	493	355	181	86	4,120,416
ACL	171	311	338	599	537	336	126	169	896,000
B&O	985	90	899	81	187	33	65	24	1,546,260
B&OCT	--	--	--	--	--	--	--	--	--
Ban & Aroos	0	0	4	1	0	0	3	1	0
B&LE	1	0	0	0	0	0	0	0	0
B&M	192	46	14	6	42	21	2	5	--
CN	244	0	222	0	338	0	502	0	498,233
CP	87	26	49	25	432	401	466	273	1,222,948
Cartier	0	0	0	0	0	0	0	0	25,650
C&O (Sys.)	122	107	35	13	139	12	33	17	--
C&EI	40	50	43	31	11	50	44	42	176,636
C&NW	1077	271	484	62	325	613	235	244	1,675,076
CB&Q	51	7	339	126	0	0	21	32	473,742
CI&L	7	1	28	5	2	0	5	2	60,900
CMStP&P	446	32	211	40	84	48	35	13	502,533
CRI&P	22	3	121	231	197	17	154	93	980,907
C&S	--	--	--	--	--	--	--	--	125,558
D&H	18	0	31	3	57	0	9	3	285,139
D&RGW	11	9	5	4	21	43	8	14	659,327
Erie-Lack	360	64	36	3	117	90	56	20	1,350,634
GTW	0	0	43	0	12	0	98	0	218,452
GN	6	0	12	2	77	48	46	26	221,573
IC	21	1	11	2	25	0	62	1	--
JCL	66	45	8	22	27	13	8	0	210,343
KCS	1	6	0	3	9	16	2	32	332,000
L&HR	9	2	7	0	7	3	3	1	9,600
LV	129	15	40	47	0	0	7	11	205,386
LI	98	47	25	7	33	8	9	2	285,000
L&N	733	629	272	304	756	469	421	131	1,850,270
Me. Cent.	4	1	19	4	1	0	16	1	2,480
MStP&SStM	109	11	27	6	69	20	48	7	124,660
MKT	910	17	0	1	104	1	0	0	589,117
MP & TP Lines	203	304	71	148	146	311	75	94	42,200
NYC (Sys.)	930	207	103	34	1585	892	214	166	2,061,060
NYNH&H	23	24	27	5	177	174	10	0	133,400
N&W (Sys.)	180	99	85	56	779	376	147	88	12,435,760
NP	42	18	63	15	121	272	143	197	496,964
PRR	840	90	2529	232	511	126	289	113	1,128,861
P&LE	0	4	0	0	21	10	2	0	6,755
QNS&L	0	0	0	0	0	1	1	1	586,000
Reading	59	43	34	0	3	2	3	0	345,110
RF&P	8	0	0	0	23	105	1	2	68,644
StL-SF	46	96	39	139	103	169	16	101	742,557
SAL	1	0	68	2	21	0	97	3	152,646
SP	215	58	234	60	2096	18	611	58	1,475,377
UP	68	24	0	1	685	127	5	0	3,382,000
W. Md.	9	0	0	0	60	21	6	1	399,840
Totals	8615	2819	6597	2333	10433	5201	4285	2077	42,106,014

TABLE 8
ACCUMULATED TRANSVERSE FISSURE FAILURES IN CONTROL-COOLED RAIL AS VERIFIED BY LABORATORY INVESTIGATION, MILL AND YEAR ROLLED TO OCTOBER 1, 1967

Mill	1936	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	Total
Algoma					2b	2a	2b	1b	1a	1a		1a 2b	1a 1b	1b	1a 12b	7b 1c	1a 1b		1a			39
Carnegie (ET)			1c		1a				2c							1c	2c					7
Colorado	*				1c		1c															2
Dominion						1b																1
Gary	1b	7b	4b	1b											1b							14
Inland	1a		3a		3a	3a	8a		1a	7a 1b	1a	2a		1a			1a	4a		2a	1a	39
Lackawanna								6a	2a	8a			3a	1a	1a	1a						22
Steelton	5a	22a	13a	11a	11a	15a 1c	6a	16a 1c	8a	1a	3a	3a	2a	4a	2a	5a	3a	4a	1a			137
Tennessee		1b					1c		2c		1o						1c					6
TOTAL	7	30	21	12	18	22	18	24	16	18	5	8	7	7	17	15	9	8	2	2	1	267

Note: (a) TRANSVERSE FISSURE from hot torn steel. (b) TRANSVERSE FISSURE from shatter cracks due to improper cooling. (c) TRANSVERSE FISSURE from inclusion. Summary - 46 T. F.'s from shatter cracks, 16 T. F.'s from inclusions, 205 T. F.'s from hot torn steel.

*No CC rail rolled.

TABLE 9

WELDED ENGINE BURNS AND FAILURES

Railroad	Engine Burns Welded Prior To 1966	Burns Welded In 1966	Failed Welded Engine Burns During 1966
AT&SF	125,255	2,446	0
B&O	9,995	DID NOT REPORT	
C&O	52,146	DISCONTINUED KEEPING THIS INFORMATION	
C&NW	23,915	1,890	1
D&H	8,305	80	12
EJ&E	93,141	16,648	0
IC	66,823	DISCONTINUED KEEPING THIS INFORMATION	
PRR	496,391	21,174	7
RF&P	18,004	14	1
STL-SF	5,318	495	0
SAL	35,933	1,769	0
Southern (West. Div.)	145,591	DID NOT REPORT	
SP	2,109	DISCONTINUED KEEPING THIS INFORMATION	
Total	1,082,926	44,516	21

TABLE 10
ANNUAL REPORT OF RAIL FAILURES, SERVICE AND DETECTED,
OCCURRING FROM JANUARY 1, 1966 TO DECEMBER 31, 1966, INCLUSIVE
IN RAIL OF ALL AGES AND SECTIONS

Section and Lb. per Yd.	Track Miles		Trans. Fiss.	Comp. Fiss. & Det. Fract.	VSH	HSH	Other Head	Broken	Web In. Jt.	Web Other	Base	All Types	Engine Burn Fract.
100 lb and less	100,418	(S)	235	168	2,570	407	2,896	2,495	14,264	921	1,134	25,090	612
		(D)	6,150	2,729	10,875	2,194	711	358	20,319	2,303	442	46,081	1,441
105 lb NYC Dudl	4,144	(S)	6	15	36	11	8	2	123	13	4	218	43
		(D)	358	237	720	142	13	4	1,133	12	1	2,620	170
106 lb CF&I	30	(S)		1			2					3	
		(D)											
107 lb NH	550	(S)	1		2	1			11			15	2
		(D)	8		5	1			25			39	
110 lb RE	3,563	(S)	44	15	44	36	19	164	188	216	5	1,031	21
		(D)	676	439	342	114	38	256	656	106		2,627	189
110 lb HF	156	(S)				6		14	51			71	
		(D)		88	18	22			48			176	2
110 lb GN	534	(S)	1	12	9	9	13		12		1	57	21
		(D)	107	10	28	1	1		5			152	13
112 lb RE	20,719	(S)	54	78	37	45	97	133	1,848	272	18	2,582	103
		(D)	784	811	225	73	278	217	3,324	275	9	5,996	919
112 lb TR	1,872	(S)				1					10	11	
		(D)		3								3	1
113 lb HF	2,715	(S)	2	66	19	27	15	48	505	6	4	692	12
		(D)		496	41	38			1,497	1		2,073	58
115 lb RE	20,941	(S)	2	50	48	24	152	60	148	25	24	833	101
		(D)	40	430	26	37	57	8	225	7	4	834	45
115 lb NYC	70	(S)											
		(D)			7	1			4			12	
119 lb CF&I	1,513	(S)		6				2	5			13	
		(D)		68		2			12			82	
122 lb CB	557	(S)	1	5				4	7	1		18	
		(D)											
127 lb NYC Dudl	5,466	(S)	10	33	19	7	10	8	328	34	3	452	57
		(D)	173	455	149	37	8		2,330	101	2	3,555	380
129 lb TR	682	(S)		2		2			6			10	7
		(D)		20								20	3
130 lb RE	2,329	(S)	15	8	24	10	78	28	117	13		293	6
		(D)	336	548	241	45	68	2	189	62		1,491	222
130 lb HF	1,023	(S)	29	1	31	12	38	61	218	17	1	408	58
		(D)	351	4	87	6	2	11	201	21		683	50
130 lb PS	3,329	(S)	33	12	43	9	29	37	944	42	11	1,160	66
		(D)	18	590	276	75	1	3	486	20	1	1,470	502
131 lb RE	11,595	(S)	44	68	32	14	66	270	610	85	8	1,197	184
		(D)	213	2,215	119	89	149	231	3,643	154	5	6,818	1,325
132 lb RE	13,491	(S)	4	64	38	10	189	14	150	40	6	515	48
		(D)	23	1,023	42	116	66	11	348	128		1,757	153
132 lb HF	1,842	(S)		60	18	67	111	5	163	2	1	427	10
		(D)		628	6	25	4		585	3		1,251	31
133 lb RE	1,702	(S)		25		1	2	6	31	4	1	70	8
		(D)		840		23			215			1,078	24
136 lb LV	680	(S)			11				88			99	25
		(D)			13	1			144			188	112
136 lb NYC	347	(S)							1	1		2	
		(D)			1				4			5	
136 lb RE	3,545	(S)		27	2	9	8	1	25			72	7
		(D)		291	1	8	1		108			109	12
140 lb RE	3,317	(S)	4	6	2	1	1	6	12		3	35	11
		(D)	3	37	2	3	2	8	23	3		81	17
152 lb PS	850	(S)	2	6	2	1	5	11	57	3	1	88	62
		(D)		220	7	7		2	75		1	312	67
155 lb PS	620	(S)		2			1	2	6			11	8
		(D)		49		3						52	12
Total	214,600	(S)	487	730	2,987	710	4,040	3,371	20,218	1,695	1,235	35,173	1,502
		(D)	9,240	12,231	13,561	3,063	1,399	1,111	35,599	3,196	465	79,865	5,748

Report on Assignment 4

Rail End Batter: Causes and Remedies

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Your committee presents as Appendix 4a, AAR Research Department's second progress report on the rail end build up service test installation on the New York Central. This report was prepared by M. J. Wisnowski, metallurgical engineer, under the direction of G. M. Magee, director of engineering research.

Appendix 4a

Rail End Build up Service Test Installation—Second Progress Report

On August 10 and 11, 1966, a rail end build up service test was installed in tangent track on the New York Central System. This installation is located 15 miles east of Toledo, Ohio, two highway intersections west of Clay Center at approximately Mile Post 278 + 23 poles. There were 30 consecutive rail joints, 15 on the south rail and 15 on the north rail, used in this service test installation.

The welding equipment was supplied by the Union Carbide Corporation, Linde Division, and consisted of an automatic wire feeder type UWM-4 voltage controlled welding machine and a UAM-2 welding torch. All battered rail ends were built up by strip welding using an experimental 921-85 cored wire on joints 1 through 26 and a 921-88c wire on joints 27 through 30. A description of this test installation, welding equipment, experimental wire, amperes–volts settings, variations in pre and post heating and hardness checks were presented in the preliminary report in the AREA Proceedings, Vol. 67, pages 473–477. A summary of the welding practice used in preparing these joints is included in Table 1 of this report for convenience.

On June 7, 1966, after approximately ten months of service (August 10 and 11, 1965 to June 7, 1966) an inspection of this rail end build up service test installation was made. At the time of this inspection approximately 21 million gross tons of traffic had passed over this installation. This is considered equivalent to 350,000 cycles in the rolling-load machine. A summary of this inspection was presented in a progress report in the AREA Proceedings, Vol. 68, pages 452–458.

On May 10, 1967 after 21 months of service (August 10 and 11, 1965 to May 10, 1967) an inspection of this installation was made by Herold Barth, representing the New York Central System; L. B. Miller, representing the Union Carbide Corporation–Linde Division; and Michael J. Wisnowski and Homer B. Johnson, representing the Association of American Railroads. Since the inception of this installation approximately 44 million gross tons of traffic had passed over this location. This is considered equivalent to 733,000 cycles in the rolling-load machine.

Rail surface profile readings were made on these 30 joints at the time of welding in 1965. It was later disclosed that a grinding train passed over these joints after they had been in service for approximately two months. Due to this grinding no correlation could be made between the original profile readings and the readings obtained during the 1966 inspection. Therefore, the profile readings obtained during the 1966 inspection will be used as a reference. A plot showing the average profile readings (1966 and 1967) of the odd numbered joints (south rail) and even numbered joints (north rail), for the two different types of welding wire used in this installation can be found in Fig. 1. It will be noted that the maximum average batter developed for the 921-85 cored wire was 0.007 in whereas, the maximum average batter developed for the 921-88c cored wire was 0.006 in. The direction of traffic is designated with an arrow in the plots shown in Fig. 1.

A visual examination of these welds showed the presence of porosity at the weld junction in joints 1, 8, 9, 11 and 23. This porosity was also distributed throughout the weld deposit of joints 12, 19, 24 and 26 and concentrated on one rail end in joint 21. Typical examples of this porosity can be seen in Figs. 2, 3 and 4. Several longitudinal cracks in the weld metal were noted on rail joints 3, 4, 5, 6, 8, 10, 12, 14 and 25. Typical examples of these longitudinal cracks can be seen in Figs. 5 and 6. Also noted was the development of small transverse cracks in the weld metal of rail joints 1, 2, 5, 6, 8, 9, 10 and 15. Typical examples of these transverse cracks can be seen in Figs. 7, 8 and 9. Both ends of joint 9, Fig. 10, broke out and small chips broke off the ends of joints 17, 18 and 23. A photograph showing a small chip broken from the end of joint 17 can be seen in Fig. 11. A complete summary of the visual observations can be found in Table 2.

To determine the extent of work hardening, spot hardness checks were taken of this weld metal deposit. It can be noted in Table 2 that the increase in BHN reading for the experimental 921-85 cored wire ranged from 6 to 65 points. An increase ranging from 15 to 35 points was noted for the 921-88c wire.

Any comments at this time as to the merits of these experimental wires for rail end build up use would be premature. This installation will be observed periodically and reported on to the committee.

TABLE 1

WELDING PRACTICE

Joint No.	Type of Wire	Amperes	Volts	Pre-Heat (^oF)	Post-Heat (^oF)
1	921-85	290-300	30-31	700^o	None
2	921-85	290-300	30-31	700^o	None
2					1200^o+
2					1100^o
3	921-85	290-300	30-31	700^o	None
4	921-85	290-300	30-31	700^o	None
5	921-85	290-300	30-31	700^o	None
6	921-85	290-300	30-31	700^o	None
7	921-85	290-300	30-31	700^o	None
7					1100^o
8	921-85	290-300	30-31	700^o	None
9	921-85	290-300	30-31	700^o	None
10	921-85	290-300	30-31	700^o	None
11	921-85	290-300	30-31	700^o	None
12	921-85	290-300	30-31	700^o	None
13	921-85	290-300	30-31	700^o	None
13					1100^o
14	921-85	290-300	30-31	700^o	None
15	921-85	290-300	30-31	700^o	None
16	921-85	290-300	30-31	700^o	None
17	921-85	290-300	30-31	700^o	None
18	921-85	290-300	30-31	700^o	None
19	921-85	340	31	900^o	None
20	921-85	315	28	900^o	None
21	921-85	315	28	700^o	1100^o
22	921-85	315	28	700^o	1100^o
23	921-85	315	28	700^o	1100^o
24	921-85	315	28	700^o	1100^o
25	921-85	315	28	700^o	None
26	921-85	315	28	900^o	None
27	921-88c	310	26-28	900^o	None
28	921-88c	310	26-28	900^o	None
29	921-88c	310	26-28	900^o	None
30	921-88c	310	26-28	900^o	None

TABLE 2

HARDNESS READINGS AND VISUAL OBSERVATIONS OF MAY 10, 1967 SERVICE TEST INSPECTION

Joint No.	Brinell Hardness Number Readings: West Rail End 8-11-65	West Rail End 6-7-66	West Rail End 5-10-67	East Rail End 8-11-65	East Rail End 6-7-66	East Rail End 5-10-67	Visual Observation
1	378	415		385	425		Porosity at weld junction of west rail. Small transverse crack in weld metal of east rail.
2	445			415			Small transverse crack in weld metal of east rail.
2	458			415			
2	415		445			415	
3	425			455			Longitudinal cracks in weld metal on gage side of both rails.
4	425			440			Longitudinal cracks in weld metal on gage side of east rail.
5	500			510			Several large longitudinal cracks on field and gage side of east rail. Two transverse cracks at end of east rail.
6	510			510			Longitudinal cracks in weld metal on gage side of west rail. Transverse crack in weld metal of east rail.
7	430			465-425			OK
7	400	415	465	435-390	418	445	
8				423			Porosity at weld junction and throughout weld metal on both rails. Several small longitudinal cracks in weld metal of west rail. Transverse crack in weld metal of east rail.
9	445			425			Porosity at weld junction on both rails. Large chip broken off both rail ends probably due to a tight joint. Several transverse cracks in weld metal of west rail.

TABLE 2 (CONTINUED)

Joint No.	Brinell Hardness Number Readings						Visual Observation
	West Rail End			East Rail End			
	8-11-65	6-7-66	5-10-67	8-11-65	6-7-66	5-10-67	
10							Longitudinal cracks in weld metal on gage side of west rail. Transverse cracks in weld metal of both rails.
11							Porosity at junction of both rails.
12	465	500		525	545		Porosity throughout weld metal on both rails. Longitudinal crack in weld metal on gage side of west rail.
13	460			460			OK
13	400		442	415		472	
14							Longitudinal cracks in weld metal on gage side of both rails.
15	465			465			Transverse crack in weld metal of east rail.
16	470-500			415			OK
17							Small chip off end of west rail.
18	425			425			East rail originally not welded to end has appearance of a slight end chip.
19	405		440	480		415	Heavy porosity throughout weld deposit on both rails.
20	440		482	425		478	OK
21	375		415	388		395	Heavy concentration of porosity on end of east rail.
22	388		400	400		438	OK
23	358		412	388		410	Porosity at fusion line in west rail. Several small chips out between weld metal and rail on field side of west rail.
24	388	415	400	388	428	440	Very light porosity in weld metal on gage side.
25	472	525	415	445	497	470	Longitudinal cracks in weld metal on gage side.

TABLE 2 (CONTINUED)

Joint No.	Brinell Hardness Number Readings						Visual Observation
	West Rail End			East Rail End			
	8-11-65	6-7-66	5-10-67	8-11-65	6-7-66	5-10-67	
26	429		435	475		490	Small amount of porosity in weld deposit on both rails.
27	415	430	415	415	415	415	OK
28	410	437	438	395	460	410	OK
29	410		440	423		445	OK
30	400	437	435	415	437	438	OK

Joints No. 1 through 26 welded with experimental 921-85 cored wire.

Joints No. 27 through 30 welded with 921-88C wire.

FIG. 1
PROFILES OF TEST JOINTS WITH BATTER BUILT UP BY SEMI-AUTOMATIC ELECTRIC WELDING WITH TWO DIFFERENT TYPES OF WELDING WIRE

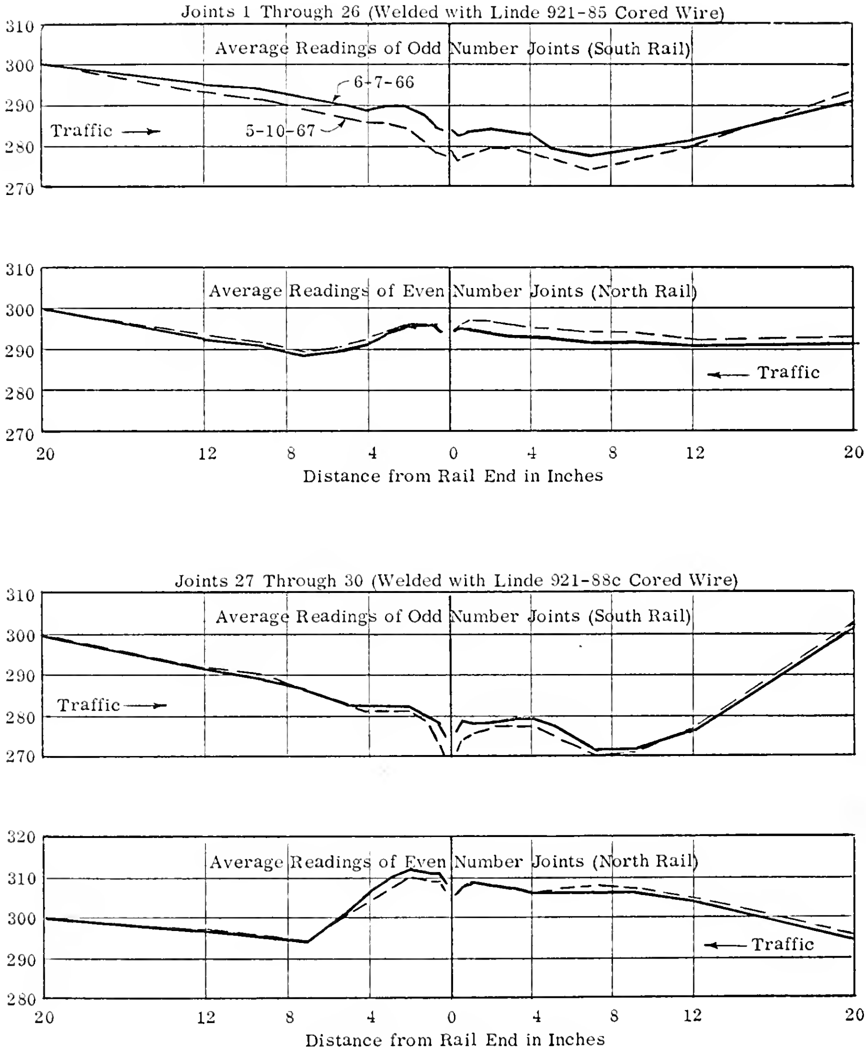


Fig. 2—Photograph of joint 11 showing porosity at weld junction of west rail.

Fig. 3—Photograph of joint 19 showing porosity throughout weld deposit on both rails.

Fig. 4—Photograph of joint 21 showing porosity on end of east rail.

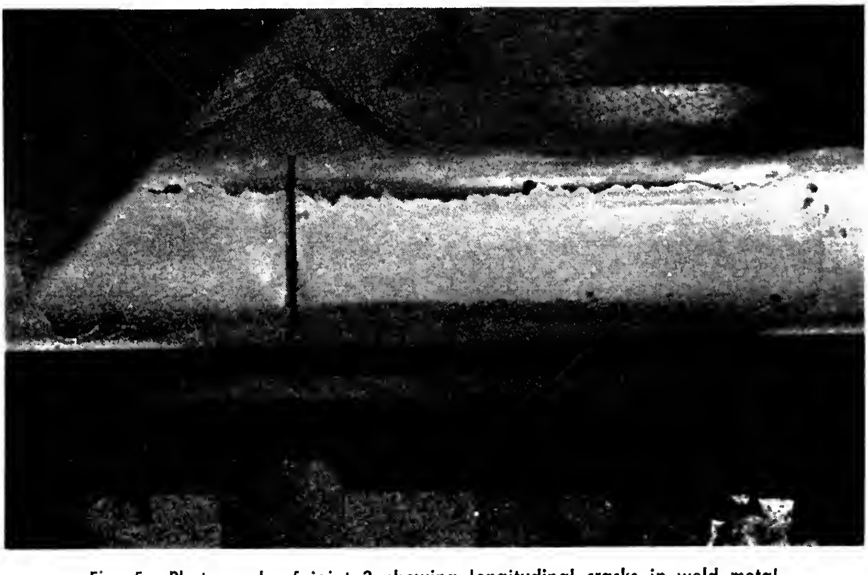


Fig. 5—Photograph of joint 3 showing longitudinal cracks in weld metal on gage side of both rails.

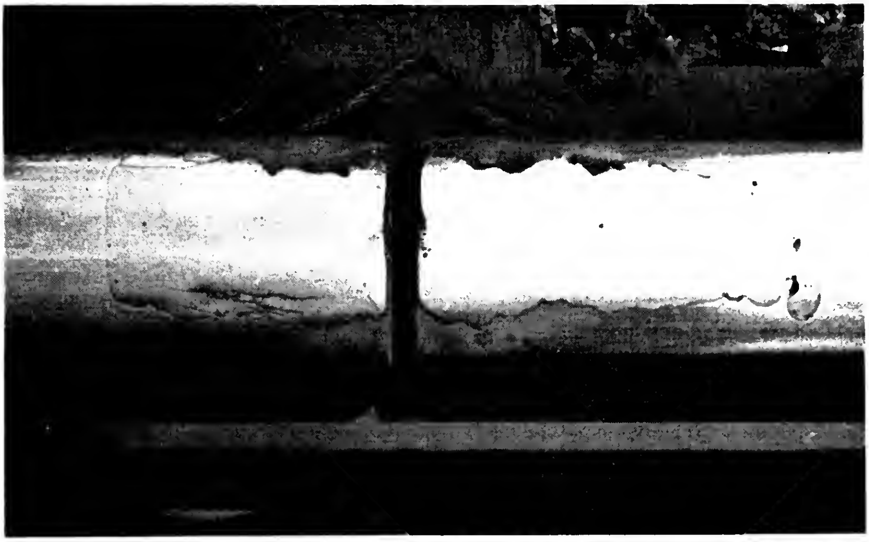


Fig. 6—Photograph of joint 5 showing longitudinal cracks in weld metal on gage and field side of east rail.

Fig. 7—Photograph of joint 2 showing a transverse crack in weld metal of west rail.

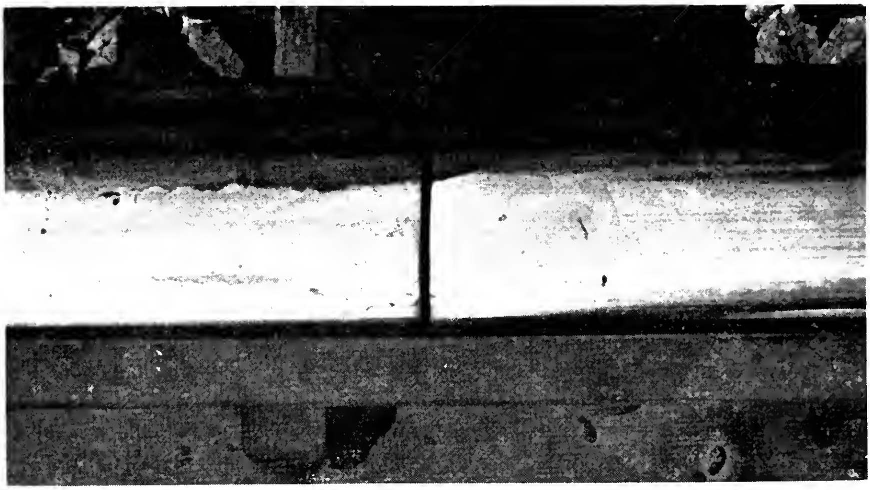


Fig. 8—Photograph of joint 6 showing a transverse crack in the weld metal of the east rail and longitudinal cracks in the weld metal on the gage side of the west rail.

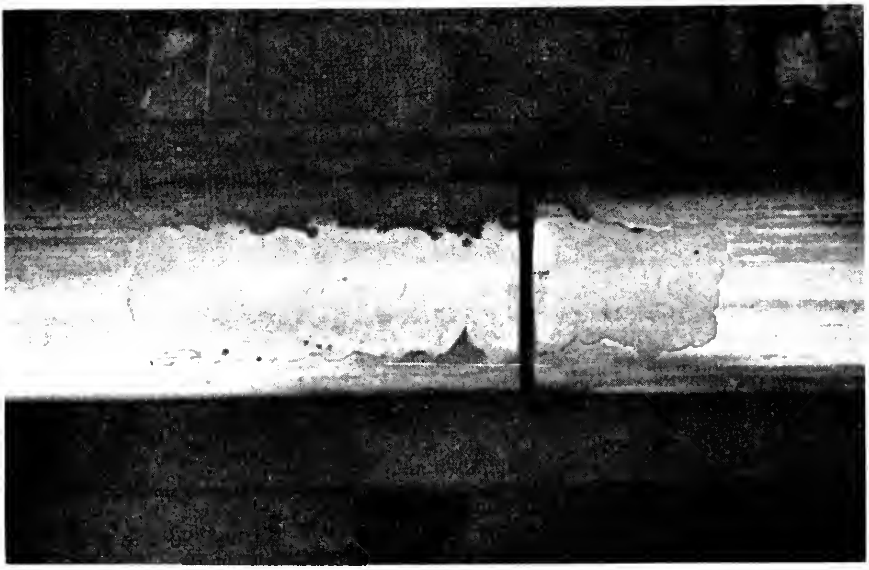


Fig. 9—Photograph of joint 10 showing transverse cracks in the weld metal of both rails and longitudinal cracks in the weld metal of the west rail.

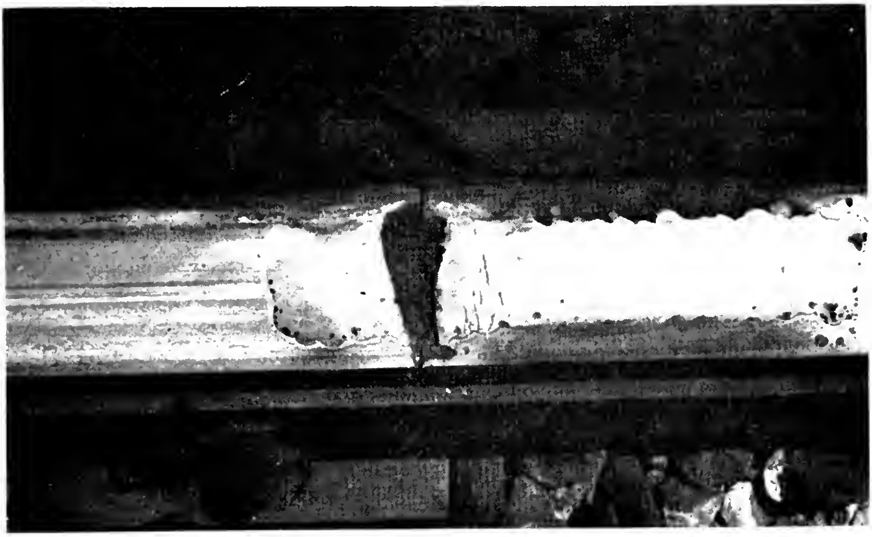


Fig. 10—Photograph of joint 9 showing a large chip broken off both rail ends.

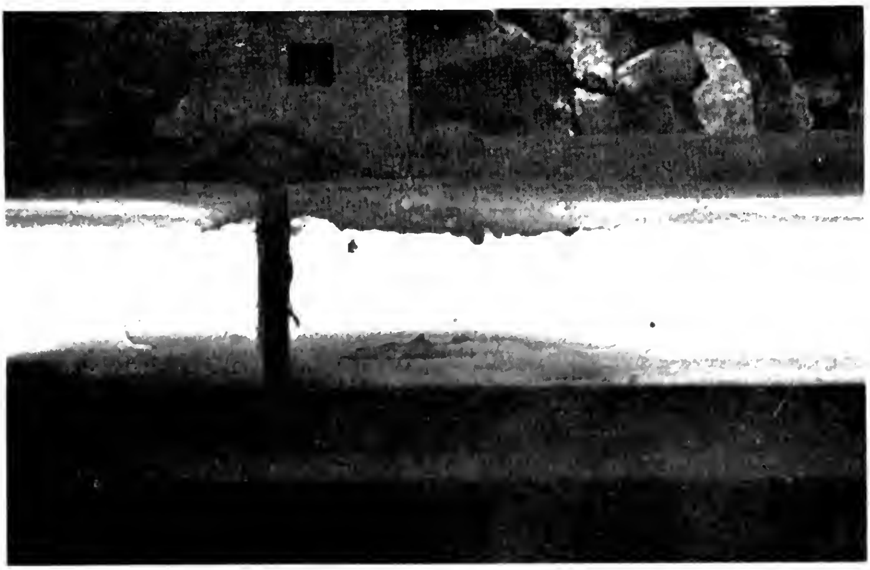


Fig. 11—Photograph of joint 17 showing a small chip broken off the end of the west rail.

Report on Assignment 8

Causes of Shelly Spots and Head Checks in Rail; Methods for Their Prevention

C. F. Parvin (chairman, subcommittee), W. D. Almy, J. B. Clark, A. N. Brauer, B. Bristow, R. F. Bush, L. S. Crane, P. K. Crucksiiank, W. J. Cruse, A. R. DeRosa, F. L. Etchison, D. T. Faries, R. E. Gorsuch, V. E. Hall, W. T. Hammond, C. J. Henry, C. C. Herrick, K. H. Kannowski, A. B. Merritt, Jr., B. R. Meyers, C. E. Morgan, B. J. Murphy, G. L. P. Plow, J. M. Rankin, R. B. Rhode, Emil Szaks, E. H. Waring, C. E. Weller, H. M. Williamson.

This is a progress report, presented as information.

During the past year work on this assignment has been conducted at the AAR Research Center by M. J. Wisnowski, metallurgical engineer, under the direction of G. M. Magee, director of engineering research. The assignment continues in two phases: One is the investigation of heat-treated rail and alloy-rail service test installations on curves with histories of shelling. The report on this phase is presented below as Appendix 8a. The other phase is the laboratory investigation involving rolling-load and slow-bend tests. Report on the laboratory investigation is included as Appendix 8b (see page 699).

Appendix 8a

Summary of Heat-Treated and Alloy Rail Service Test Installations on Curves with Shelly Histories—1967

GREAT NORTHERN RAILWAY

Service Test of Rails Rolled from Continuously Cast Blooms

Continuously cast blooms approximately 9.5 in square were produced from a 35-ton electric furnace heat by the Fives Gille Company of Cail, France. The blooms, of 0.66 carbon and 0.75 manganese steel were rolled into rails at Huttenwerk Rheinhausen, Germany, on October 10, 1961, in section S49M (German), approximately 98.57 lb per yd.

After considerable testing at the AAR Research Laboratory and the University of Illinois, four rails were installed on October 13, 1964, by the Great Northern in its No. 1 lead track at the east end of the Allouez, Wis., yard.

The four 39-ft rails were laid in the high side of a 7-deg 30-min curve, with 1¾ in superelevation. The rails were joined together with four-hole 90-lb GN joint bars. The end rails were joined by machined four-hole compromise joint bars to 110-lb GN rails (1937). All bolt holes in the rails were drilled in the field.

On June 21, 1967, after carrying 18,450,469 gross tons of traffic, tonnage figured to May 31, 1967, these rails were inspected. Moderate curve wear, light head checks and light flaking were noted on each of the four rails. The three west rails were marked by wheel burns. Otherwise the installation appeared normal. There was little or no evidence of lubrication on the rails.

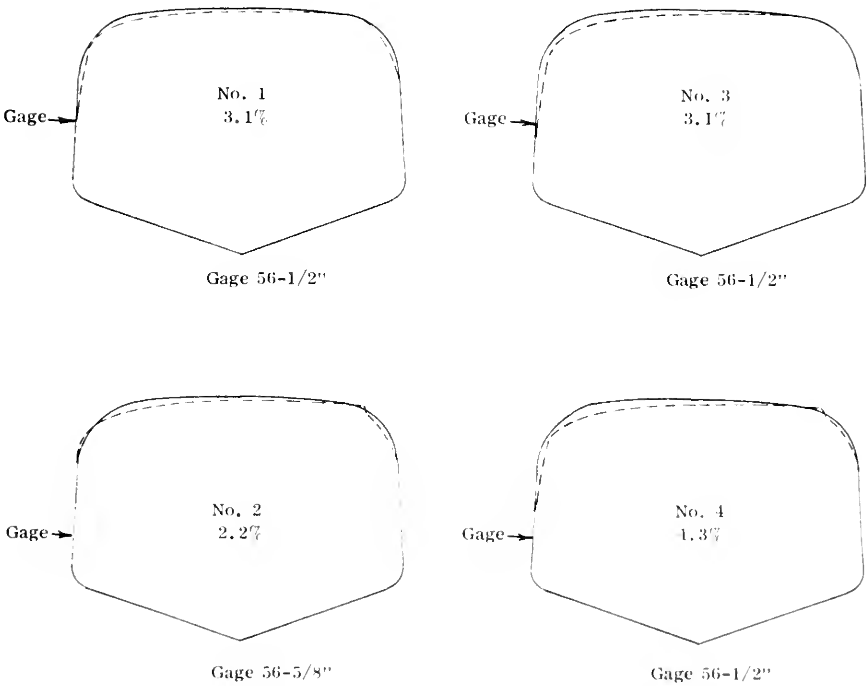
Contour tracings were made at a point 10 ft from the west or receiving end of each rail and are shown in Fig. 1. The track gage at the points of contour was 56½ in for three rails and 56⅝ in for the fourth.

Considerably more service will be required before any conclusions can be drawn on the relative merits of such rails.

FIGURE 1
GREAT NORTHERN RAILWAY
100 LB RAIL GERMAN SECTION S-49M
ROLLED FROM CONTINUOUSLY CAST BLOOMS
PLACED OCTOBER 13, 1964 IN LEAD NO. 1, ALLOUEZ
YARD ON A 7°30' CURVE WITH SUPERELEVATION - 1-3/4"
AT SUPERIOR, WISCONSIN

HIGH RAIL ONLY

INSPECTION DATE 6-21-67



Tonnage to May 31, 1967 - 18,150,169 G.T.

Service Test of 115 RE Fully Heat-Treated Rails (Curve 20)

This installation of 115 RE fully heat-treated rails on the Great Northern Railway's ore-carrying track east of Carlton, Minn. was extensively described in the AREA Proceedings, Vol. 57, pages 837–850, and Vol. 63, pages 540–543.

The 88 fully heat-treated rails were installed in both the high and low sides of the 4 deg curve No. 20 on February 7, 1951. On May 17, 1961, 65 of the rails were transposed after 384,000,000 gross tons of traffic. During this same period two sets of ordinary rails were worn out in the high side of the comparative 4 deg curve No. 22.

Almost 123 million gross tons of traffic have passed over the rails from the time of the transposition, to May 31, 1967, bringing the total gross tons carried to 506,961,961.

The present condition of each of the heat-treated rails now in the high side of curve No. 20 is shown in the following tabulation. At the time of the June 1965 inspection a small shell was noted in two rails. Three additional shells were found in one of these rails, and three other rails were noted to contain small shells at the time of the 1966 inspection. Small shells were observed in 6 additional rails at the time of this 1967 inspection, bringing the total to 11 rails containing shells. Generally speaking there was little change in the flaking observed in the last two years in most of the rails in the full curvature portion of the high side. The low-side rails appeared in good condition. All the rails have taken the transposition very well but are starting to show an increase in typical service developments.

The curve oiler appeared to be functioning properly and all rails were well lubricated.

Contour tracings were made on both high- and low-side rails and are shown in Figs. 2, 3 and 4 (see pages 670 through 672).

RAILS INSTALLED FEBRUARY 7, 1951. HIGH-SIDE RAILS NOS. 7 THROUGH 38 WERE MOVED TO LOW SIDE OF CURVE AND WERE REPLACED BY LOW-SIDE RAILS IN DIRECT TRANSPOSITION MAY 17, 1961. RAILS NUMBERED 1 TO 6 AND 39 TO 43 WERE NOT TRANSPOSED. THE CONDITION OF THE HIGH SIDE RAILS AT THE TIME OF THIS JUNE 21, 1967 INSPECTION (C) IS SHOWN ALONG WITH THE JUNE 21, 1966 (B) AND THE JUNE 10, 1965 (A) OBSERVATIONS. ASTERISK INDICATES CONTOUR TAKEN 10′ FROM RECEIVING END. CONTOUR TAKEN DIRECTLY OPPOSITE ON LOW ( ) AND GAGE MEASUREMENT SHOWN.

Rail No.	*Identity*	*Remarks*
1	B9	(A) Clear—not transposed (B) Clear—not transposed (C) Clear—not transposed
2	H14 Replaced with standard Illinois rail as indicated	(A) Clear—not transposed (B) H14 rail moved into low side of curve to replace rail E3 which cracked through build-up weld into 2nd bolt hole (C) Same as (B)
3	H11	(A) Clear—not transposed (B) Clear—not transposed (C) Clear—not transposed

Rail No.	*Identity*	*Remarks*
4	F12	(A) Clear—not transposed (B) Clear—not transposed (C) Clear—not transposed
5	D8	(A) Clear—not transposed (B) Clear—not transposed (C) Clear—not transposed
6	F1 (curve oiler rail)	(A) Clear—not transposed (B) Clear—not transposed (C) Clear—not transposed
7	E12	(A) Clear (B) Clear (C) Clear
8	H10	(A) Clear (B) Clear (C) Clear
9	*F8 $56\frac{3}{8}''$ (H12) $56\frac{3}{8}''$ $56\frac{3}{8}''$	(A) Engine burn 4′ from leaving end (B) Engine burn 4′ from leaving end (C) Engine burn 4′ from leaving end
10	G4	(A) Light flakes (B) Light flakes intermittently throughout, heavy flakes 10′ from leaving end (C) Light flakes intermittently throughout, heavy flakes 10′ from leaving end
11	E5	(A) Heavy flaking throughout (B) 5 shells with flaking throughout (C) 8 shells with several possible additional shells and heavy flaking
12	H5	(A) Heavy flaking throughout (B) Medium flaking throughout (C) Heavy flaking intermittently throughout
13	*B13 $56\frac{5}{8}''$ (F10) $56\frac{3}{4}''$ $56\frac{3}{4}''$	(A) Light flaking (B) Light flaking (C) Light flaking
14	F6	(A) Light flaking (B) Light flaking (C) Light to medium flaking throughout
15	C12	(A) Medium flaking throughout with shell 12′ from leaving end (B) Medium flaking throughout with shell at 12′ from leaving end. Also 3 possible shells (C) Medium flaking with shell 12′ from leaving end. Possible 6 additional shells at mid-rail
16	C5	(A) Very light flaking (B) Very light flaking (C) Very light flaking

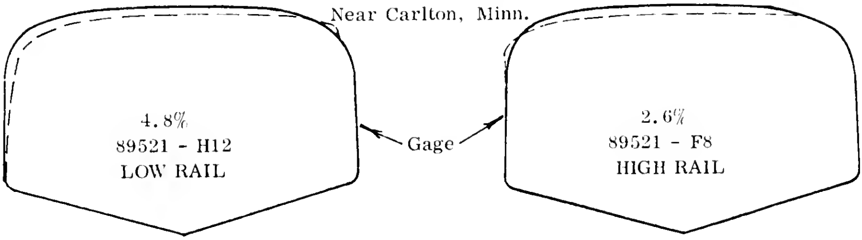
Rail No.	*Identity*	*Remarks*
17	*E9 56⅝″ (F3) 56¾″ 56⅝″	(A) Light intermittent flaking (B) Light intermittent flaking (C) Medium intermittent flaking
	E3 removed from low side and replaced by H14	
18	E13	(A) Medium flaking leaving half (B) Medium flaking leaving half (C) Medium flaking leaving half and light flaking receiving half
19	C7	(A) Very light flaking (B) Very light flaking (C) Light flaking
20	B12	(A) Very light flaking (B) Very light flaking (C) Very light flaking with 2 medium flaking areas
21	*G14 56⅝″ (B3) 56¾″ 56¾″	(A) Light flaking leaving half (B) Light flaking leaving half (C) Light flaking throughout
22	G12	(A) Very light flaking (B) Few medium flaking spots throughout (C) Few medium flaking spots throughout
23	G13	(A) Head checks (B) Head checks (C) Light flaking
24	E14	(A) Medium to heavy flaking particularly in receiving half (B) Medium to heaving flaking in receiving half (C) Heavy flaking with 2 shells 10′ from leaving end
25	*H3 56⅝″ (B10) 56¾″ 56¾″	(A) Very light intermittent flaking (B) Very light intermittent flaking (C) 2 shells 5′ and 11′ from receiving end
26	C9	(A) Clear (B) Head checks throughout (C) Clear
27	F11	(A) Clear (B) Light flaking and head checks throughout (C) 1 shell 30″ from receiving end. Medium flaking areas receiving ⅓
28	B11	(A) Medium flaking (B) Medium flaking (C) Medium flaking and 5 scattered small shells
29	*E8 56⅝″ (D6) 56¾″ 56¾″	(A) Very light intermittent flaking (B) Very light flaking and head checks (C) 3 possible shell areas—joint bar area receiving end and 9′ to 12′ from leaving end

Rail No.	*Identity*	*Remarks*
30	C13	(A) Medium flaking areas. Leaving end recently welded (B) Light flaking—welded end OK (C) Medium flaking
31	H2	(A) Light intermittent flaking leaving half. Receiving end recently welded (B) Welded end chipped slightly. Light flaking. Possible shell 5′ from leaving end (C) 1 shell 5′ from leaving end and several possible shells
32	E7	(A) Light intermittent flaking (B) Head checks (C) Light intermittent flaking
33	*H6 56¾″ (C7) 56⅞″ 56¾″	(A) Medium flaking. (Some surface tearing apparently from developments when rail was on low side) (B) Three small shells. Surface about as noted above (C) 8 small shells mid-rail
34	D5	(A) Light flaking receiving end (B) Light flaking receiving end (C) Shell 4″ from receiving end. Medium flaking throughout
35	F5	(A) Medium flaking (B) Medium to heavy flaking (C) Medium to heavy flaking
36	G1	(A) Light flaking center of length (B) Medium flaking center of length (C) Medium flaking center of length
37	*B5 56⅝″ (G3) 56¾″ 56¾″	(A) Head checks (B) Head checks (C) Head checks
38	H1	(A) Head checks (B) Head checks (C) Head checks
39	B8	(A) Clear—not transposed (B) Clear—not transposed (C) Clear—not transposed
40	C6	(A) Clear—not transposed (B) Shell 6′ from receiving end (Tangent track) (C) Shell 6′ from receiving end
41	C3	(A) Clear—not transposed (B) Clear—not transposed (C) Clear—not transposed
42	E2	(A) Clear—not transposed (B) Clear—not transposed (C) Clear—not transposed
43	F14	(A) Clear—not transposed (B) Clear—not transposed (C) Clear—not transposed

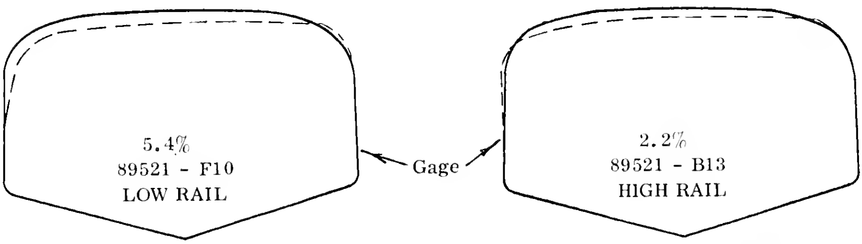
FIGURE 2
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB (FULLY HEAT TREATED)

DIVISION Mesabi
Laid Feb. 7, 1951

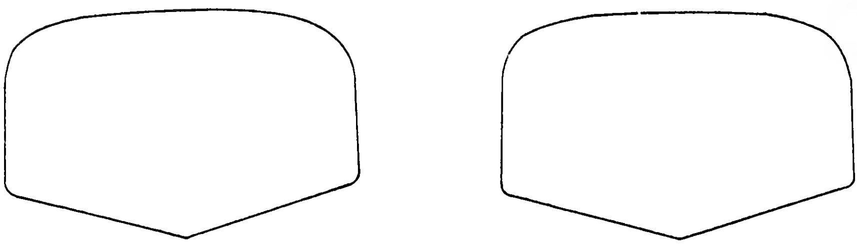
INSPECTION DATE 6-21-67
Transposed May 17, 1961



M.P. 33, CURVE NO. 20, DEGREE 4°, Superelevation 3", Gage 56-3/8"



M.P. 33, CURVE NO. 20, DEGREE 4°, Superelevation 3", Gage 56-3/4"



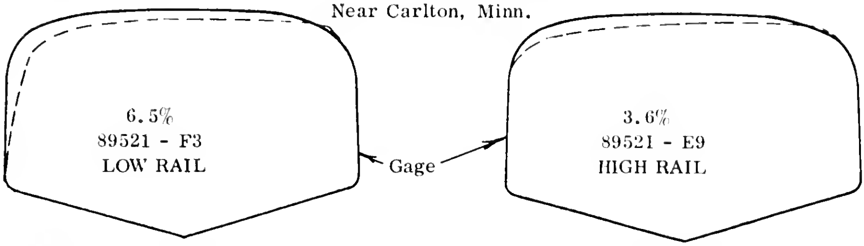
Tonnage to August 24, 1961 - 394,225,777 G.T.
Tonnage to May 31, 1967 - 506,961,961 G.T.

FIGURE 3
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB (FULLY HEAT TREATED)

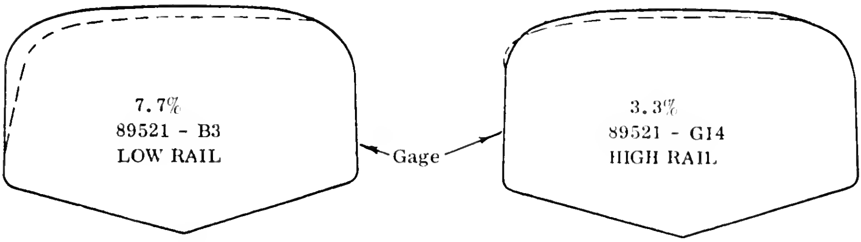
DIVISION Mesabi
Laid Feb. 7, 1951

INSPECTION DATE 6-21-67
Transposed May 17, 1961

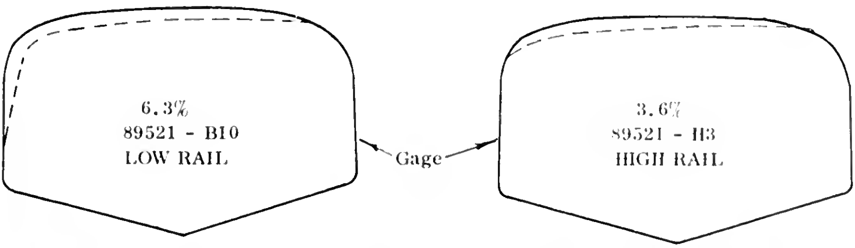
Near Carlton, Minn.



M.P. 33, CURVE NO. 20, DEGREE 4°, Superelevation 3", Gage 56-5/8"



M.P. 33, CURVE NO. 20, DEGREE 4°, Superelevation 3", Gage 56-3/4"



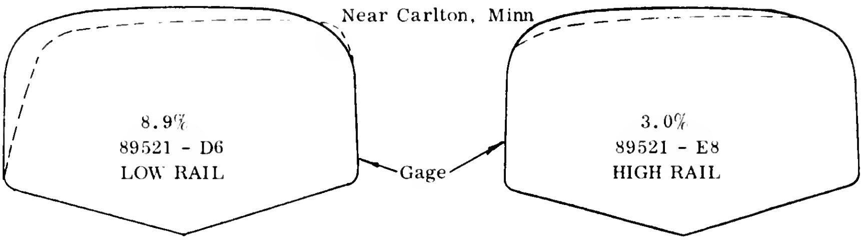
M.P. 33, CURVE NO. 20, DEGREE 4°, Superelevation 3", Gage 56-3/4"

Tonnage to August 24, 1961 - 394,225,777 G.T.
Tonnage to May 31, 1967 - 506,961,961 G.T.

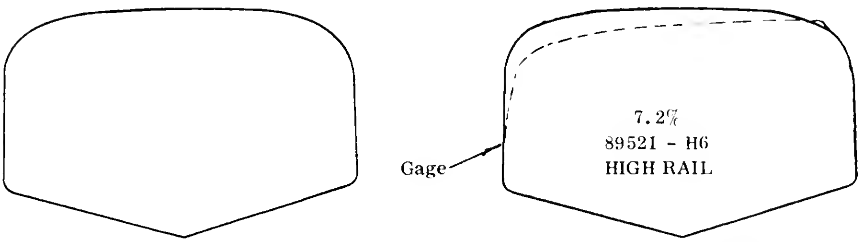
FIGURE 4
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB (FULLY HEAT TREATED)

DIVISION Mesabi
Laid Feb. 7, 1951

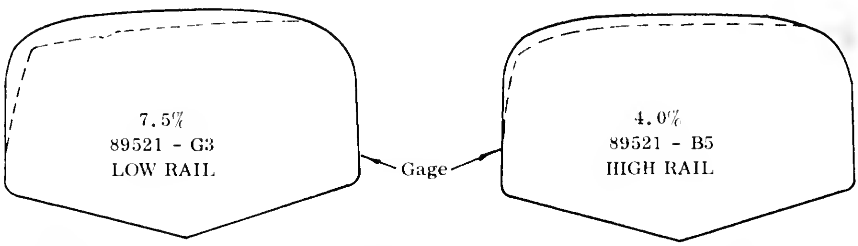
INSPECTION DATE 6-21-67
Transposed May 17, 1961



M.P. 33, CURVE NO. 20, DEGREE 4°, Superelevation 3", Gage 56-3/4"



M.P. 33, CURVE NO. 20, DEGREE 4°, Superelevation 3", Gage 56-3/4"



M.P. 33, CURVE NO. 20, DEGREE 4°, Superelevation 3", Gage 56-3/4"

Tonnage to August 24, 1961 - 394,225,777 G.T.
Tonnage to May 31, 1967 - 506,961,961 G.T.

Service Test of 115 RE Fully Heat-Treated 78-Ft Electric Flash Butt Welded and 39-Ft Columbium-Treated Rails (Curve 22)

An inspection of the 78-ft electric flash butt welded fully heat-treated and 39-ft Columbium-treated rails installed on the Great Northern Railway's ore-carrying track east of Carlton, Minn. was made on June 21, 1967. The 115-lb RE Columbium-treated rail was extensively described in the AREA Proceedings, Vol. 63, pages 533–535.

Following removal of the second set of regular non-heat-treated rails from the 4-deg curve No. 22 which were being compared with the fully heat-treated rails in the 4-deg No. 20 curve, curve No. 22 was laid with Columbium-treated and 78-ft butt welded fully heat-treated rails on May 17, 1961.

Starting in the spiral at the west end of the curve, 8 rails of steel bearing different amounts of Columbium were installed in the high side and 7 rails in the low side of the curve. The section 1150 Columbian rails were produced by CF&I Steel Corp. from steel bearing ¼ lb, ½ lb and 1 lb Columbium per ton.

One 78-ft flash butt welded fully heat-treated rail preceded and 16 followed the Columbium-treated rails in both the high and low sides of this curve. The fully heat-treated rails were produced at Steelton and were flash welded into 78 ft lengths by the Great Northern (NCG).

The following tabulation shows the original track lineup of the rails and notes the conditions observed at the time of the June 10, 1965 inspection (A), the June 21, 1966 inspection (B), and the current 1967 inspection (C). It will be noted that the 78-ft fully heat-treated rail preceding the Columbium-treated rails in both the high and low sides of the curve was lost in a derailment in 1964.

By the time of this inspection both the Columbium-treated and fully heat-treated rails had carried approximately 112,736,184 gross tons of traffic. Three of the Columbium rails have been removed on account of service developments and four of the five remaining in the high side of the curve have developed from 2 to 9 shells each, and numerous more suspicious areas were observed. Only the first Columbium rail in the receiving end of the curve (¼ lb ton Cb) showed no evidence of shelling at the time of this inspection. It would appear that the rails having the greater amounts of Columbium have less resistance to these service developments. More service will be required to make sure of this situation.

In the meantime, the 78-ft flash butt welded fully heat-treated rails look good. No gage-corner service developments were noted, and wear and metal flow appeared to be at a minimum. There appeared to be evidence that since the 1965 inspection, head checks had developed in the gage corner of the head of some of the rails in the mid-portion of the curve, but have since worn away. The gage corner of all the fully heat-treated rails appeared smooth at the time of this inspection. The weld areas showed no evidence of additional flow. In fact it was necessary to search the web area for the upset in most cases to locate the welds.

Contour tracings were made on rails indicated with an asterisk in the following tabulation. These tracings are shown in Figs. 5, 6, 7 and 8. (See pages 676 through 679).

SECTION 115 RE—78-FT FLASH BUTT WELDED FULLY HEAT-TREATED RAILS—STEELTON (CT)—ROLLED 12/1960. SECTION 1150—39-FT COLUMBIUM-TREATED RAILS—CF&I (CB)—ROLLED 3/1960

(A) 6/10/65 Inspection. (B) 6/21/66 Inspection. (C) 6/21/67 Inspection.

Starting in Tangent—West to East

High (North) Rail	*Low (South) Rail*
78′ CT48366–F7/48326–B14 (lost in derailment 1964)	78′ CT82175–E12/48327–E13 (lost in derailment 1964)
39′ 12143–E7C (¼ lb/ton Cb) *(A) Clear. Slight flow *(B) Clear. Moderate flow. Gage 56½″ *(C) Clear. Moderate flow. Gage 56½″	39′ 12143–C7C (¼ lb/ton Cb) *(A) Moderate flow *(B) Moderate flow. Gage 56½″ *(C) Moderate flow. Gage 56 7/16″
39′ 12143–F8C (½ lb/ton Cb) *(A) Clear. Slight flow *(B) 2 shells—18″ and 6′ from leaving end. Moderate flow. Gage 56⅝″ *(C) 4 shells: 18″, 3′, 5′, 6′ from receiving end. 2 suspicious areas 7′ to 8′. Gage 56½″	39′ 12143–D7C (¼ lb/ton Cb) *(A) Moderate flow *(B) Moderate flow. Gage 56⅝″ *(C) Moderate flow. Gage 56⅝″
39′ 12143–E8C (½ lb/ton Cb) *(A) Medium flaking for 6″ in joint bar area receiving end. Two shells at 13′ and 18″ and 2 possible shells at 6′ and 12′ from receiving end. Moderate flow *(B) Heavy flaking 18″ receiving end. 7 large and 7 small shells in receiving 30′. Gage 56⅝″ *(C) Removed April 1967 a/c detected detail fracture	39′12143–C8C (½ lb/ton Cb) *(A) Moderate flow *(B) Moderate flow. Slight burns 12′ and 3′ from leaving end. Gage 56⅝″ *(C) Moderate flow. Burns still noted. Gage 56 7/16″
39′ 12143–E9C (1 lb/ton Cb) *(A) Eleven shells 9′ from receiving toward leaving end. Moderate flow and wear *(B) Used Inland rail replaced Columbium rail in 1965 due to detector car indication *(C) Same as (B)	39′ 12143–C9C (1 lb/ton Cb) *(A) Moderate fllow *(B) Moderate flow. Gage 56⅝″ *(C) Moderate flow. Gage 56 7/16″
39′ 12143–F9C (1 lb/ton Cb) *(A) Three shells at 15′, 26′ and 27′ from receiving end. Medium flaking leaving half. Moderate flow and wear *(B) 7 small shells. Medium flaking leaving half. Gage 56⅝″ *(C) 9 small shells plus several suspicious areas. Medium flaking. Gage 56⅝″	39′ 12143–D9C (1 lb/ton Cb) *(A) Moderate flow *(B) Moderate flow. Gage 56⅝″ *(C) Moderate flow. Gage 56¾″ Slight wheel slip marks leaving half
39′ 12143–A9C (1 lb/ton Cb) *(A) Fifteen shells throughout. Moderate flow and wear *(B) Moderate flow and wear. 10 large and numerous small shells throughout. Gage 56⅝″ *(C) Removed but date unknown	39′ 12143–A8C (½ lb/ton Cb) *(A) Moderate flow *(B) Moderate flow. Gage 56¾″ *(C) Moderate flow. Gage 56⅝″ Slight wheel slip marks receiving 5′

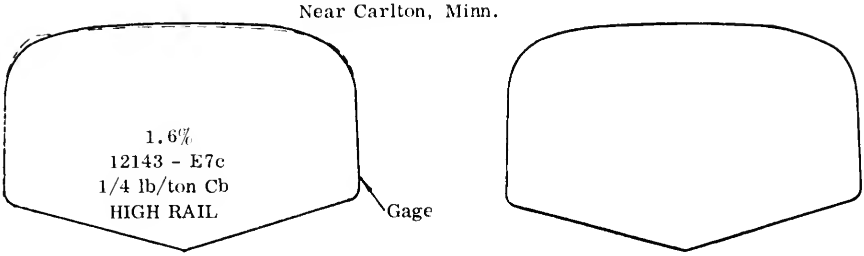
High (North) Rail	*Low (South) Rail*
39′ 12143—D8C (½ lb/ton Cb) *(A) Head checks and light flaking midrail. Moderate flow and wear middle third. Gage 56⅝″ *(B) Flaking and 3 small shells middle third. Gage 56⅝″ *(C) 3 shells plus numerous suspicious spots. Gage 56¾″	39′ 12143–F7C (¼ lb/ton Cb) *(A) Moderate flow *(B) Moderate flow *(C) Moderate flow. Gage 56¾″
39′ 12143–A7C (¼ lb/ton Cb) *(A) One shell 15′ from receiving end and two possible shells in receiving end joint bar area *(B) Flaking receiving joint bar area. Shell 15′ from receiving end and 1′ from leaving end. Gage 56¾″ *(C) Shell 15′ from receiving end and 1′ from leaving end plus numerous posible shells. Gage 56¾″	78′ *CT82175–F1/48327–E12 (A) (See Below) (B) (See Below) *(C) (See Below)
78′ *CT82175–F12/48326–G15 (A) (See Below) (B) (See Below) *(C) (See Below)	78′ CT82175–E6/82175–B17
78′ CT82175–D8/48326–B17	78′ CT82175–G10–48326–E15
78′ CT48326–F9/48326–D12	78′ CT82175–G13/48327–C13
78′ CT83275–B5/48326–D15	78′ *CT48326–E8/48326–F12
78′ *CT82175–D9/48326–F11	78′ CT48326–G7/48327–G20
78′ CT82175–E4/48326–D10	78′ CT88325–D19/82175–F17
78′ CT48326–H7/48326–H13	78′ CT88326–F19/48326–F15
78′ CT82175–G4/48326–C15	78′ CT48326–F19/48327–F12
78′ CT82175–C1/48326–H11	78′ *CT82175–G11/48326–D14
78′ *CT82175–F7/48326–D17	78′ CT82175–G1/48327–D12
78′ CT82175–H4/48326–G11	78′ CT82175–E1/48326–C17
78′ CT82175–H14/82175–F18	78′ CT82175–B8/48326–F17
78′ CT48326–G10/48326–B11	78′ CT82175–B3/48326–E12
78′ CT82175–D13/48326–H12 (last rail in spiral)	78′ CT48326–C7/48326–E13
78′ CT82175–E7/82175–F15	78′ CT82175–F4/82175–G16
78′ CT82175–G6/48326–C14	

*Contour tracings taken 10′ from receiving end. The fully heat-treated rails showed very little flow in the high and low rails, markedly less than the Columbium rails at the time of each inspection. Evidence of head checks, which are now worn away, was noted in the gage corner of the high rails in the middle of the curve.

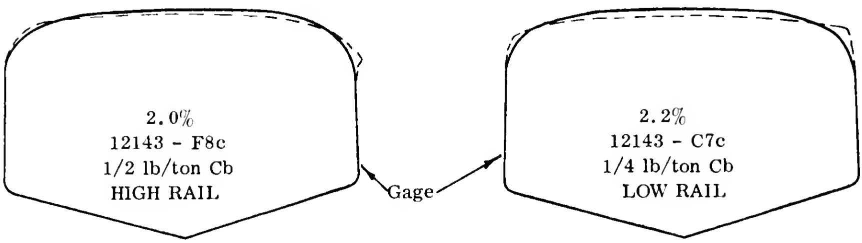
FIGURE 5
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB (COLUMBIUM ADDED)

DIVISION Mesabi INSPECTION DATE 6-21-67

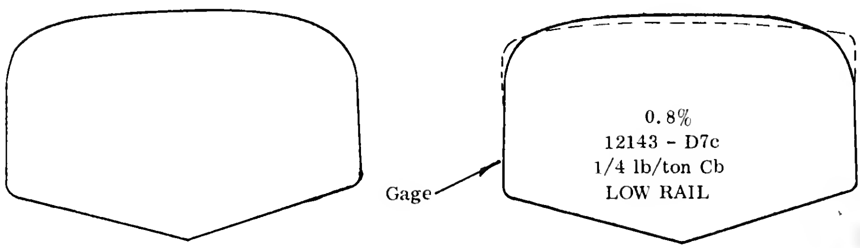
Laid May 19, 1961
Near Carlton, Minn.



M.P. 34, CURVE NO. 22, DEGREE 4°, Superelevation 3", Gage 56-1/2"



M.P. 34, CURVE NO. 22, DEGREE 4°, Superelevation 3", Gage 56-1/2"



M.P. 34, CURVE NO. 22, DEGREE 4°, Superelevation 3", Gage 56-5/8"

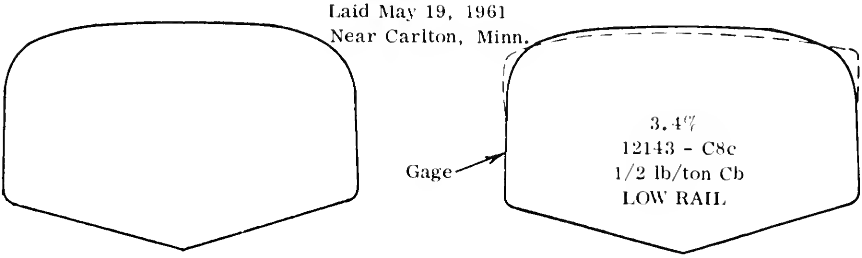
Tonnage to May 31, 1967 - 112,736,004 G.T.

FIGURE 6
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB (COLUMBIUM ADDED)

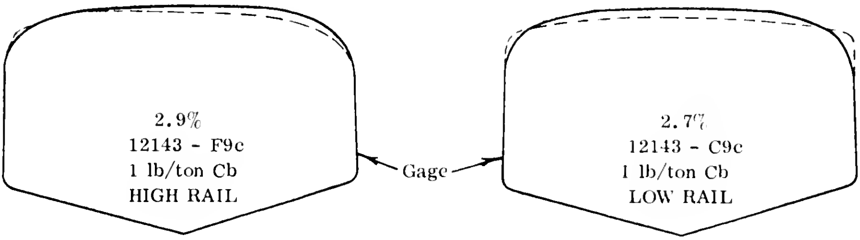
DIVISION Mesabi

INSPECTION DATE 6-21-67

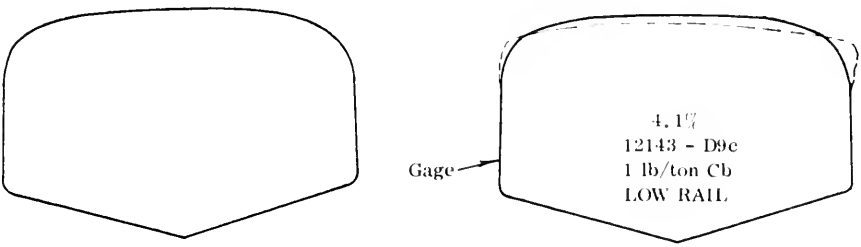
Laid May 19, 1961
Near Carlton, Minn.



M.P. 34, CURVE NO. 22, DEGREE 4°, Superelevation 3", Gage 56-1/2"



M.P. 34, CURVE NO. 22, DEGREE 4°, Superelevation 3", Gage 56-5/8"

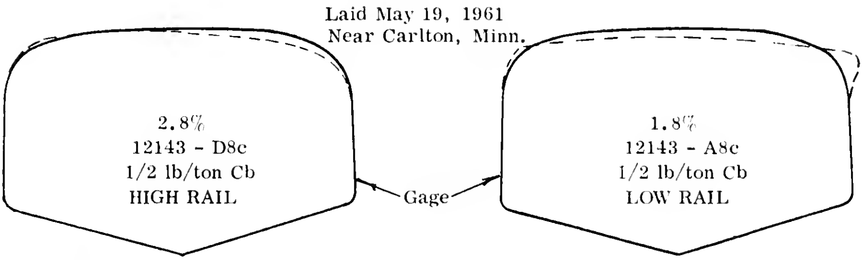


M.P. 34, CURVE NO. 22, DEGREE 4°, Superelevation 3", Gage 56-3/4"

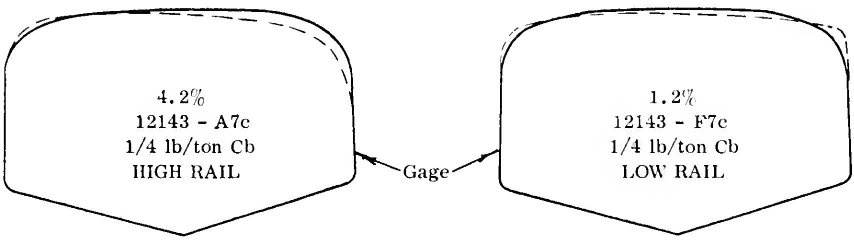
Tonnage to May 31, 1967 - 112,736,004 G.T.

FIGURE 7
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB (COLUMBIUM ADDED)

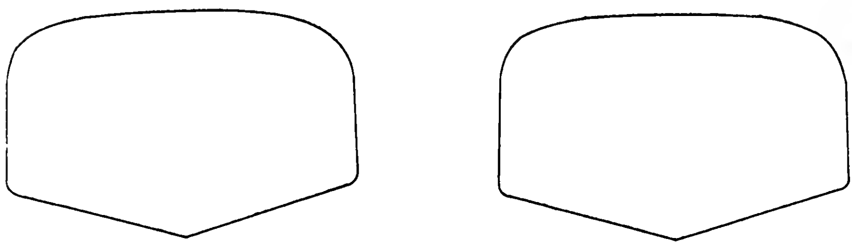
DIVISION Mesabi INSPECTION DATE 6-21-67



M.P. 34, CURVE NO. 22, DEGREE 4^{o}, Superelevation 3", Gage 56-5/8"



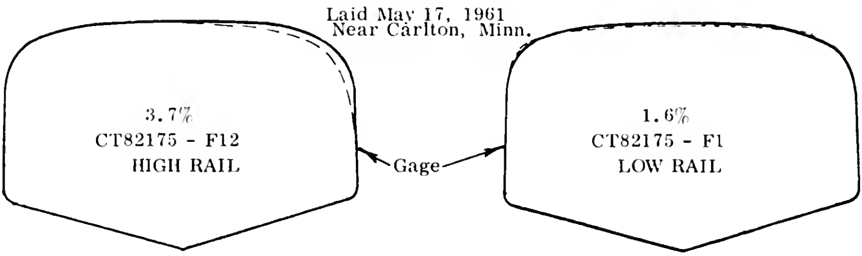
M.P. 34, CURVE NO. 22, DEGREE 4^{o}, Superelevation 3", Gage 56-3/4"



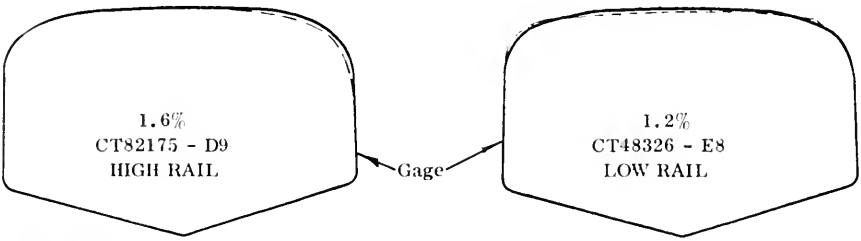
Tonnage to May 31, 1967 - 112,736,004 G.T.

FIGURE 8
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB (78 FT FULLY HEAT TREATED)

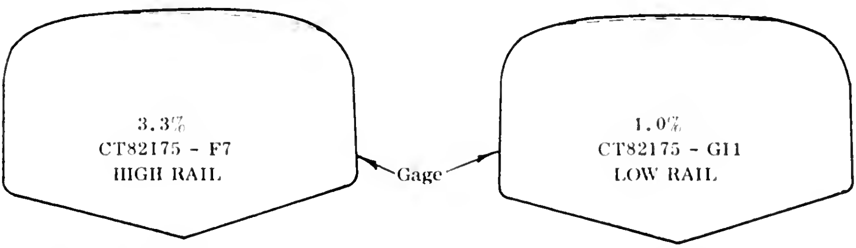
DIVISION Mesabi INSPECTION DATE 6-21-67



M.P. 34, CURVE NO. 22, DEGREE 4°, Superelevation 3", Gage 56-5/8"



M.P. 34, CURVE NO. 22, DEGREE 4°, Superelevation 3", Gage 56-5/8"



M.P. 34, CURVE NO. 22, DEGREE 4°, Superelevation 3", Gage 56-5/8"

Tonnage to May 31, 1967 - 112,736,184 G.T.

Service Test of 115 RE Curvemaster and Fully Heat-Treated Rails (Curves 125, 133 and 136)

The Great Northern established a service test of Curvemaster rails in the westbound track, in double-track territory, between Blacktail and Nimrod, about 70 miles west of Cutbank, Mont., on August 5 and 6, 1964. The surface-hardened rails were installed in one curve, No. 125. Two nearby curves, No. 133 and No. 136, of somewhat similar characteristics, in which fully heat-treated rails had been installed, were selected for comparison purposes. The details of the installations and the characteristics of the curves are recorded in the Proceedings, Vol. 67, Bulletin 598, pages 496 and 499.

Rails previously installed in these curves were usually transposed for the first time in about 3 years, with a possible overall life of up to 12 years. To the time of this inspection, September 19, 1967, the rails had been in service over three years and had carried approximately 31,452,580 gross tons of traffic, tonnage figured to August 1, 1967.

As reported previously, the wear pattern on the head of the high- and low-side rails in Curve No. 125 appeared normal, while the wear pattern throughout Curves No. 133 and No. 136 appeared abnormal in that the pattern was toward the field side in the low rails and on the gage half of the head in the high rails.

Some wear and flow was noted in the rails in the three curves, but no flaking, shelling or crushing was observed. At least four rails in Curve No. 125 were marked by wheel burns: low-side rails D27 at 3 ft from west end and D25 at 5 ft from east end and 12 ft and 3 ft from west end, and high-side rails E31 twice at midrail and B29 at spots opposite burns in rail D25, as previously reported.

Curve oilers are a considerable distance from these curves, so lubrication was negligible at the time of this inspection.

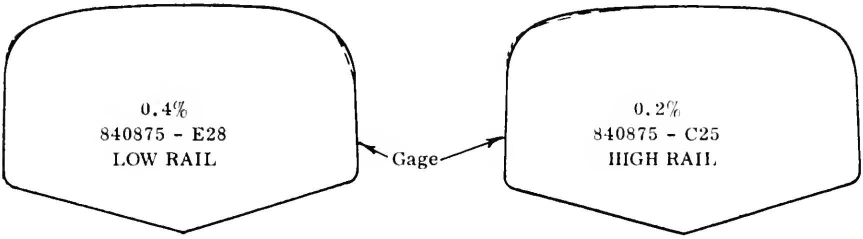
Cross section contours were taken at about the center of the leaving (or west) 39-ft half of the 78-ft rails and are shown in Figs. 9 through 16.

While it is still early in the life of these rails, it is obvious that comparison of the two types will be complicated by the track variations which have existed since installation.

FIGURE 9
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB CURVE MASTER

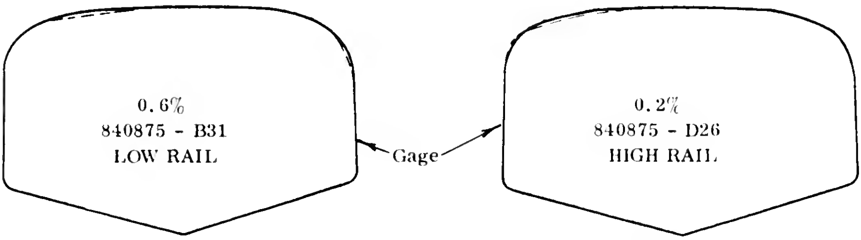
DIVISION Kalispell
Laid August 5, 1964

INSPECTION DATE 9-19-67
Between Summit and Essex



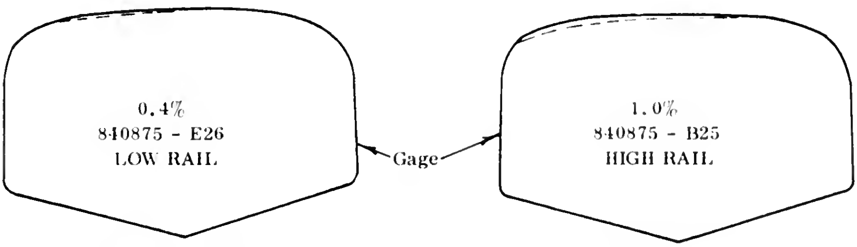
Gage 56-1/2" Gage 56-1/2"

M.P. 1161+11, CURVE NO. WB125, DEGREE 6°35'00", Superelevation 4-3/4"



Gage 56-1/2" Gage 56-1/2"

M.P. 1161+11, CURVE NO. WB125, DEGREE 6°35'00", Superelevation 4-3/4"



Gage 56-3/4" Gage 56-3/4"

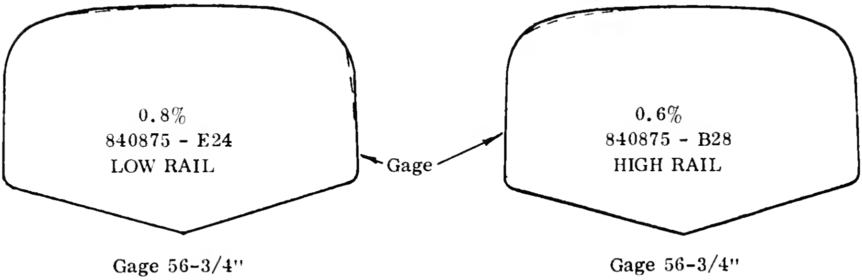
M.P. 1161+11, CURVE NO. WB125, DEGREE 6°35'00", Superelevation 4-3/4"

Tonnage to August 1, 1967 - 31,452,580 G.T.

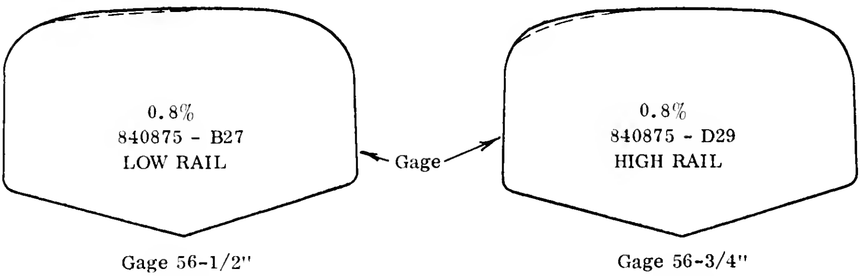
FIGURE 10
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB CURVE MASTER

DIVISION Kalispell
Laid August 5, 1964

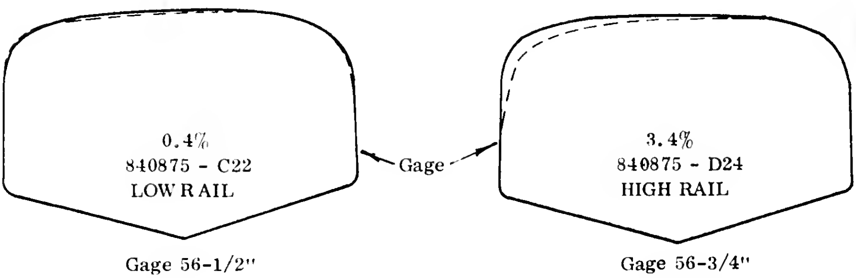
INSPECTION DATE 9-19-67
Between Summit and Essex



M.P. 1161+11, CURVE NO. WB125, DEGREE $6^{o}35'00''$, Superelevation 4-3/4"



M.P. 1161+11, CURVE NO. WB125, DEGREE $6^{o}35'00''$, Superelevation 4-3/4"



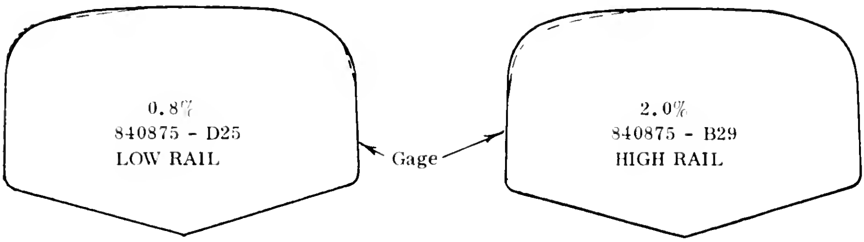
M.P. 1161+11, CURVE NO. WB125, DEGREE $6^{o}35'00''$, Superelevation 4-3/4"

Tonnage to August 1, 1967 - 31,452,580 G.T.

FIGURE 11
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB CURVE MASTER

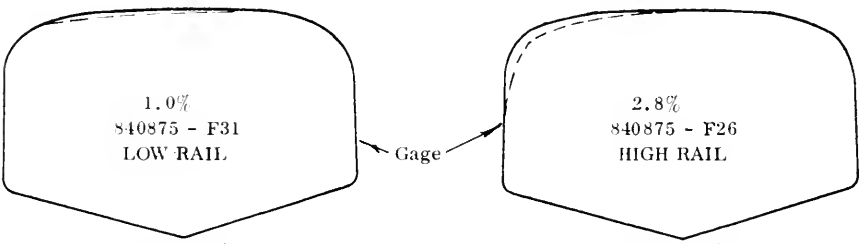
DIVISION Kalispell
Laid August 5, 1964

INSPECTION DATE 9-19-67
Between Summit and Essex



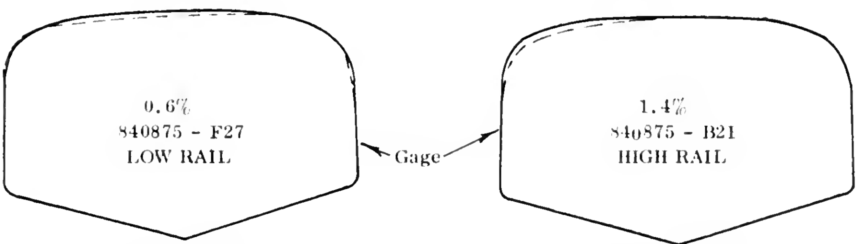
Gage 56-3/4" Gage 56-3/4"

M.P. 1161+11, CURVE NO. WB125, DEGREE 6°35'00", Superelevation 4-3/4"



Gage 56-3/4" Gage 56-3/4"

M.P. 1161+11, CURVE NO. WB125, DEGREE 6°35'00", Superelevation 4-3/4"



Gage 56-3/4" Gage 56-3/4"

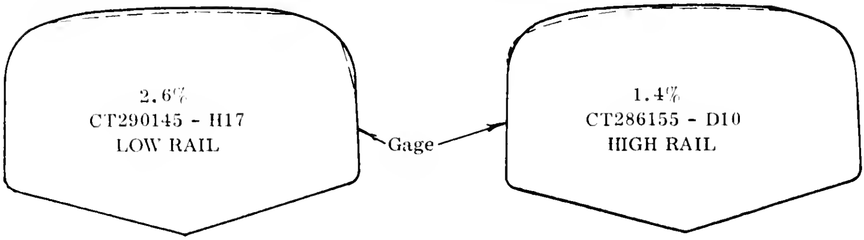
M.P. 1161+11, CURVE NO. WB125, DEGREE 6°35'00", Superelevation 4-3/4"

Tonnage to August 1, 1967 - 31,452,580 G.T.

FIGURE 12
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB FULLY HEAT TREATED

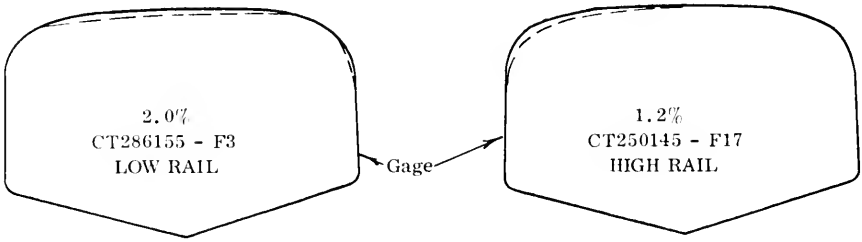
DIVISION Kalispell
Laid August 5, 1964

INSPECTION DATE 9-19-67
Between Summit and Essex



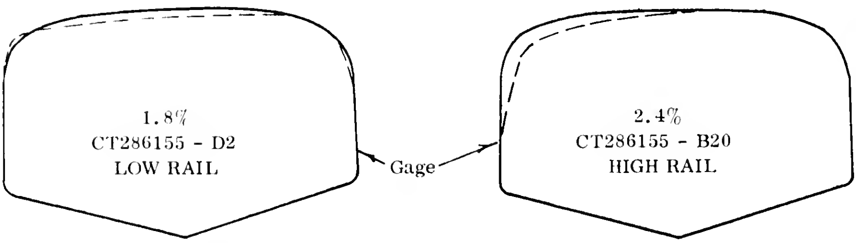
Gage 56-1/2" Gage 56-1/2"

M.P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"



Gage 56-1/2" Gage 56-1/2"

M.P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"



Gage 56-3/4" Gage 56-3/4"

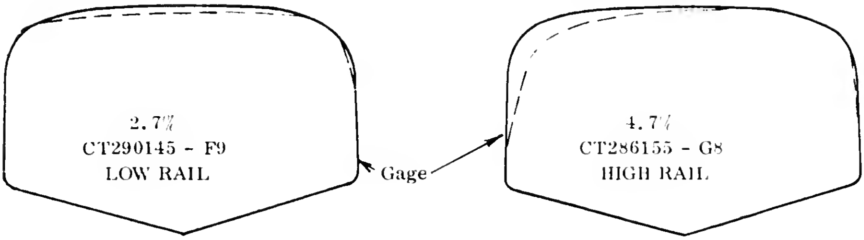
M.P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"

Tonnage to August 1, 1967 - 31,452,580 G.T.

FIGURE 13
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB FULLY HEAT TREATED

DIVISION Kalispell
Laid August 5, 1964

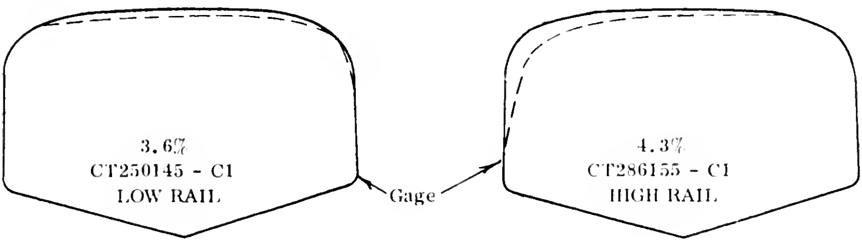
INSPECTION DATE 9-19-67
Between Summit and Essex



Gage 56-3/4"

Gage 57"

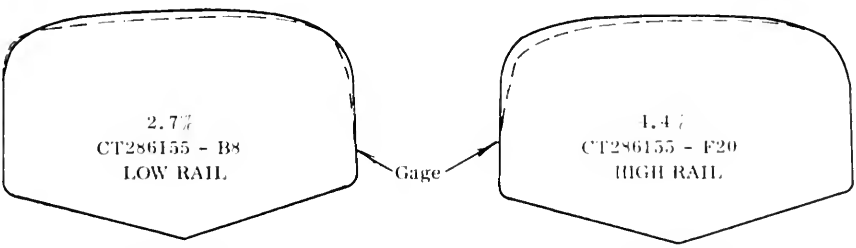
M.P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"



Gage 56-3/4"

Gage 56-3/4"

M.P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"



Gage 56-3/4"

Gage 56-3/4"

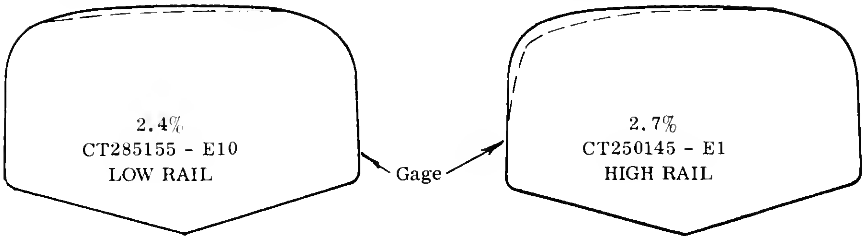
M.P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"

Tonnage to August 1, 1967 - 31,452,580 G.T.

FIGURE 14
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB FULLY HEAT TREATED

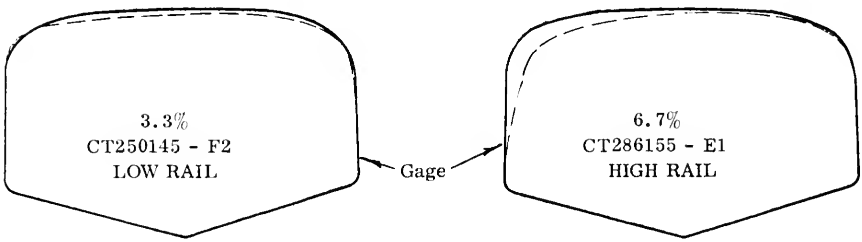
DIVISION Kalispell
Laid August 5, 1964

INSPECTION DATE 9-19-67
Between Summit and Essex



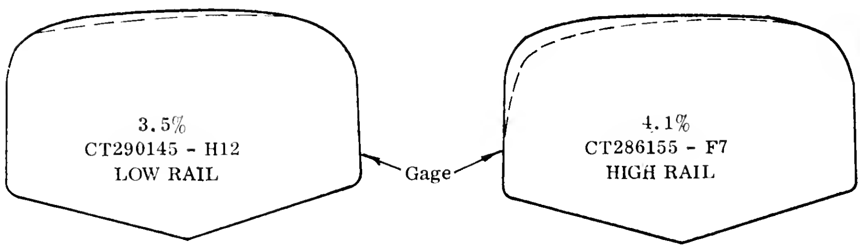
Gage 56-3/4" Gage 56-3/4"

M.P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"



Gage 56-3/4" Gage 56-3/4"

M.P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"



Gage 56-3/4" Gage 56-3/4"

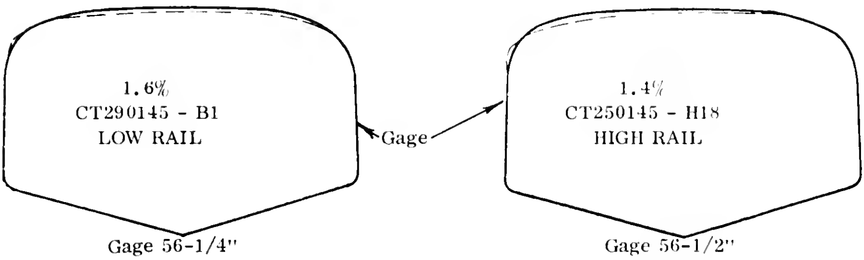
M.P. 1162.65, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"

Tonnage to August 11 1967 - 31,452,580 G.T.

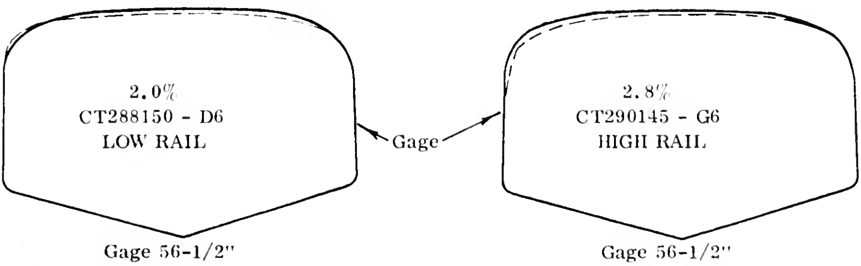
FIGURE 15
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB FULLY HEAT TREATED

DIVISION Kalispell
Laid August 5, 1964

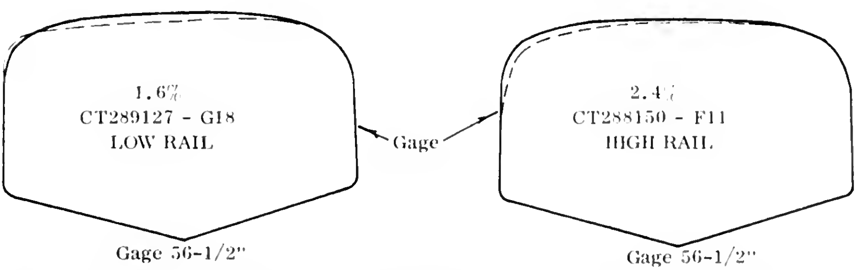
INSPECTION DATE 9-19-67
Between Summit and Essex



M.P. 1163.4, CURVE NO. WB136, DEGREE 6°15'00", Superelevation 3-1/2"



M.P. 1163.4, CURVE NO. WB136, DEGREE 6°15'00", Superelevation 3-1/2"



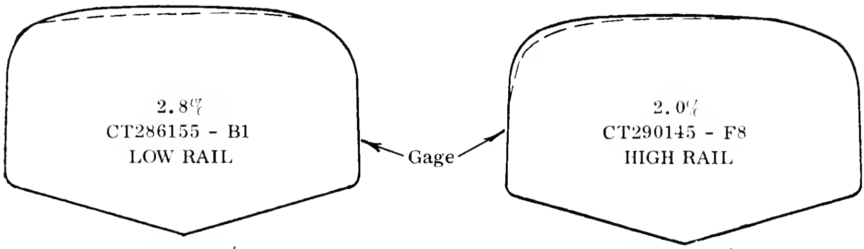
M.P. 1163.4, CURVE NO. WB136, DEGREE 6°15'00", Superelevation 3-1/2"

Tonnage to August 1, 1967 - 31,452,580 G.T.

FIGURE 16
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB FULLY HEAT TREATED

DIVISION Kalispell
Laid August 5, 1964

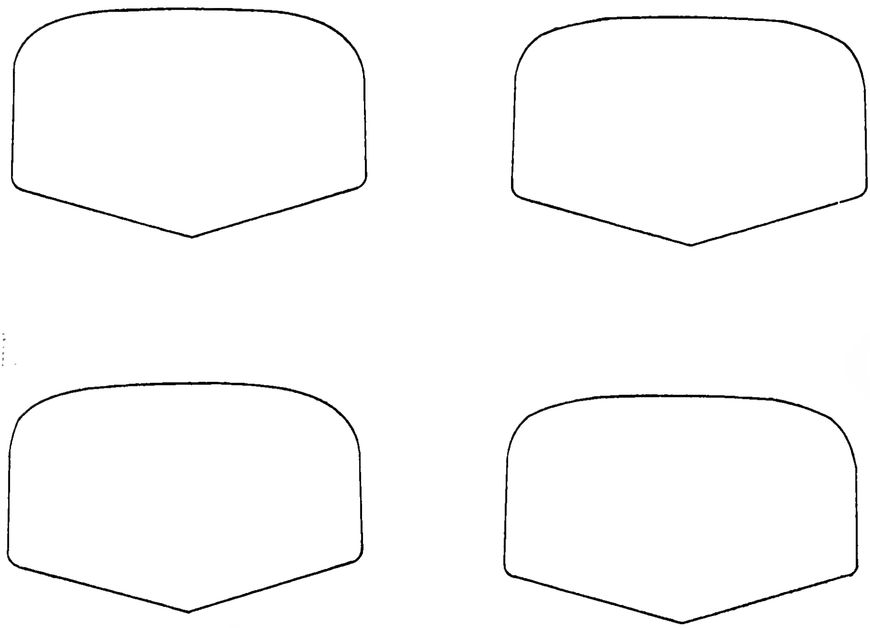
INSPECTION DATE 9-19-67
Between Summit and Essex



Gage 56-1/2"

Gage 56-1/2"

M.P. 1163.4, CURVE NO. WB136, DEGREE 6° 15'00", Superelevation 3-1/2"



Tonnage to August 1, 1967 - 31,452,580 G.T.

Service Test of 115 RE High-Silicon Rails (Curves 705, 710, 48 and 52)

The Great Northern installed high-silicon (0.71 Si) 115 RE rails in the 4-deg 59-min Curve No. 710, and regular comparative rails in the 5-deg 00-min Curve No. 705 near Camden, Wash. in September 1955. This service test was installed to investigate the properties of high-silicon rail in regard to its abrasion and shelling resistance. These installations were described extensively in the AREA Proceedings, Vol. 58, page 1028.

At the time of the August 1964 inspection, after more than 145,000,000 gross tons of traffic, 6 of the 20 standard rails in the high side of Curve No. 705 were noted to contain shells, 2 with heavy shells and 4 with medium to light shells, and 3 rails contained medium flaking areas.

Fourteen of the 31 high-silicon rails in the high side of Curve No. 710 contained shells, 8 heavy and 6 medium to light. One rail had been removed on February 3, 1964 due to a detected progressive fracture from shelling.

By October 4, 1965, after 179,496,347 gross tons of traffic, 12 of the 20 standard rails contained shells. In two rails, 12143-C16 and 12143-B16, the shells extended almost to the center line of the top of the rail head. Another rail showed flaking throughout its length.

At the same time 24 of the 31 high-silicon rails were found to contain shelling to some extent, several throughout the rail length. Rail 16191-D16 appeared to be most heavily shelled.

In October 1965 the rails in both curves were transposed. Two low-side high-silicon rails were not moved to the high side of Curve No. 710 for reasons unknown at this time. Two high-side standard carbon rails (12143-C16 and B16) were not moved to the low side of Curve No. 705 due to the heavy shelling noted above.

By the time of this September 20, 1967, inspection, approximately 40,462,289 gross tons of traffic had passed over the rails in their transposed positions. No gage corner service developments were observed, but chipping of the head surface, in some instances close to the gage corner, in areas of former low-side crushing was noted in two high-silicon rails in Curve No. 710 and in 13 standard carbon rails in Curve No. 705, the condition in the latter rails being considerably more severe.

Chipping of the head surface in the joints at the end of the rails which was observed in 5 of the high-side high-silicon rails at the time of the 1966 inspection had been repaired by welding prior to this 1967 inspection. An additional high-silicon rail, 16191-F16, was removed from the low side of Curve No. 710 in April 1967 due to a detected detail fracture.

The rails in both curves have been well lubricated throughout the test period. The curve oiler is in the fourth rail east of the first high-side test rails in Curve No. 710, and at the west end of the curve for the high rails in Curve No. 705.

Contour tracings were made at each curve and are shown in Figs. 17 through 20.

On September 21, 1967, the high-silicon (0.62 Si) rails in the 2-deg 30-min 45-sec Curve No. 48 and the regular comparative rails in the 2-deg 30 min Curve No. 52 near Winton, Wash. were inspected. These 115 RE test rails were installed by the Great Northern in July 1955.

At the time of the 1964 inspection a small shell was noted in high-silicon rail 1162-B17 in Curve No. 48. No service developments were noted in the regular rails in Curve No. 52.

During the August 1965 inspection, after approximately 97,499,749 gross tons of traffic, 3 high-silicon rails in Curve No. 48 were found to contain light to medium

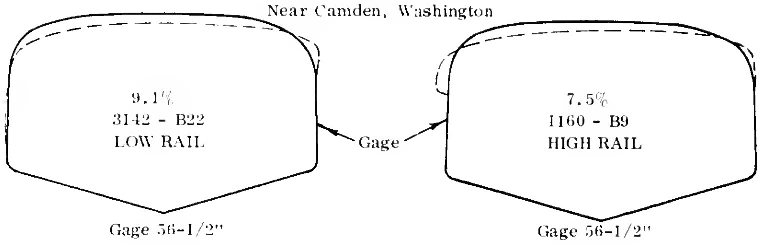
(Text continued on page 694)

FIGURE 17
GREAT NORTHERN RAILWAY
RAIL S' 'TION RE 115 LB STD. CARBON

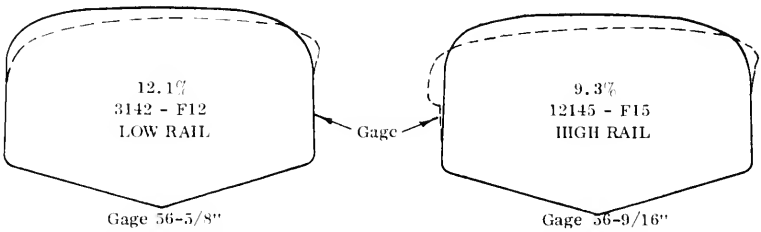
DIVISION Kalispell
Laid Sept., 1955

INSPECTION DATE 9-20-67
Transposed October, 1965

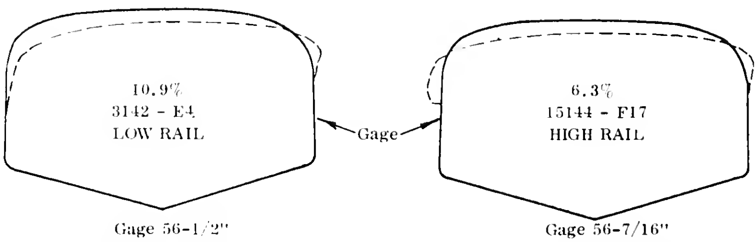
Near Camden, Washington



M.P. 1443+ , CURVE NO. 705, DEGREE 5°00', LENGTH 761', Superelevation 3-1/2", Lubricated



M.P. 1443+ , CURVE NO. 705, DEGREE 5°00', LENGTH 761', Superelevation 3-1/2", Lubricated



M.P. 1443+ , CURVE NO. 705, DEGREE 5°00', LENGTH 761', Superelevation 3-1/2", Lubricated

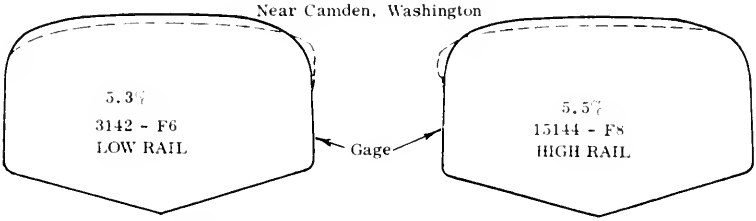
Tonnage to August 1, 1965 - 179,496,347 G.T.
Tonnage to August 1, 1967 - 219,958,636 G.T.

FIGURE 18
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB STD. CARBON

DIVISION Kalispell
Laid Sept., 1955

INSPECTION DATE 9-20-67
Transposed October, 1965

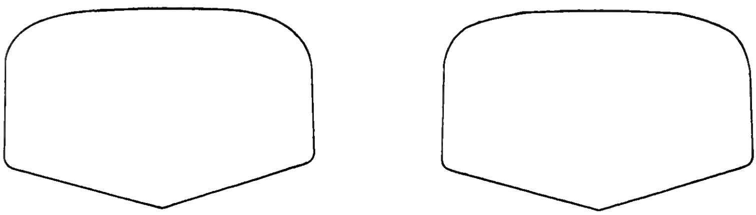
Near Camden, Washington

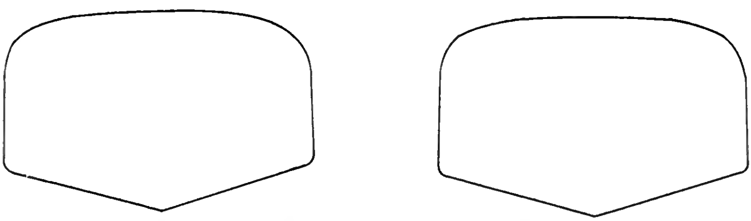


Gage 56-1 2"

Gage 56-7 16"

M.P. 1443, CURVE NO. 705, DEGREE 5°00', LENGTH 761', Superelevation 3-1/2", Lubricated





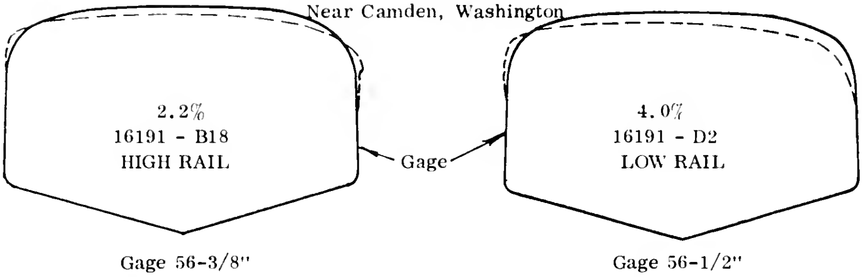
Tonnage to August 1, 1965 - 179,496,347 G.T.
Tonnage to August 1, 1967 - 219,958,636 G.T.

FIGURE 19
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB HIGH SILICON

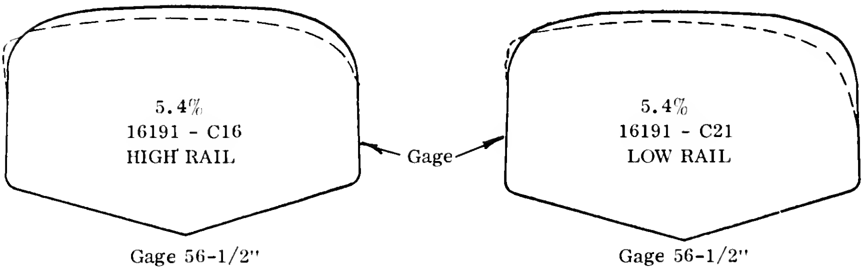
DIVISION Kalispell
Laid Sept., 1955

INSPECTION DATE 9-20-67
Transposed October, 1965

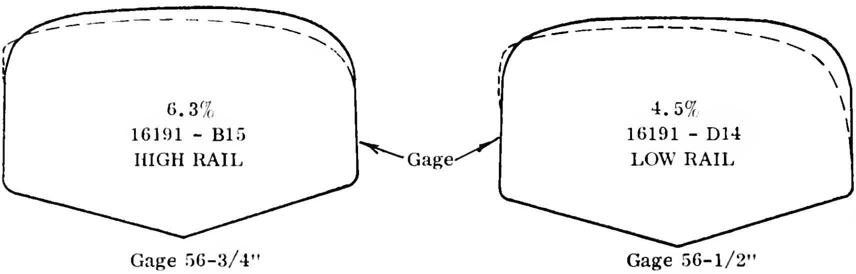
Near Camden, Washington



M.P. 1444+ , CURVE NO. 710, DEGREE 4°59', Superelevation 5-1/4", Lubricated



M.P. 1444+ , CURVE NO. 710, DEGREE 4°59', Superelevation 5-1/4", Lubricated



M.P. 1444+ , CURVE NO. 710, DEGREE 4°59', Superelevation 5-1/4", Lubricated

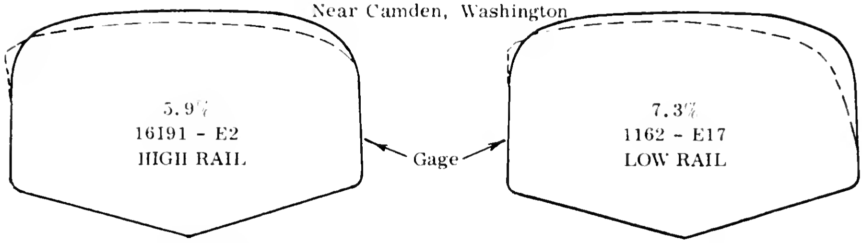
Tonnage to August 1, 1965 - 179,496,347 G.T.
Tonnage to August 1, 1967 - 219,958,636 G.T.

FIGURE 20
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB HIGH SILICON

DIVISION Kalispell
Laid Sept., 1955

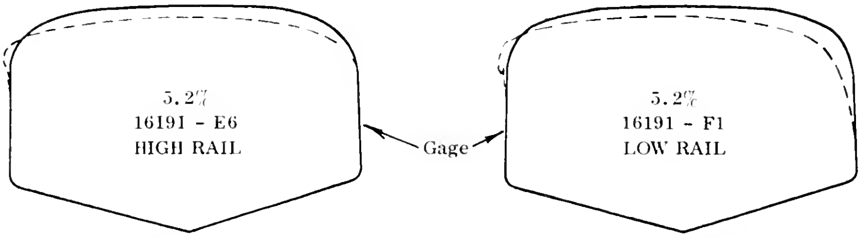
INSPECTION DATE 9-20-67
Transposed October, 1965

Near Camden, Washington



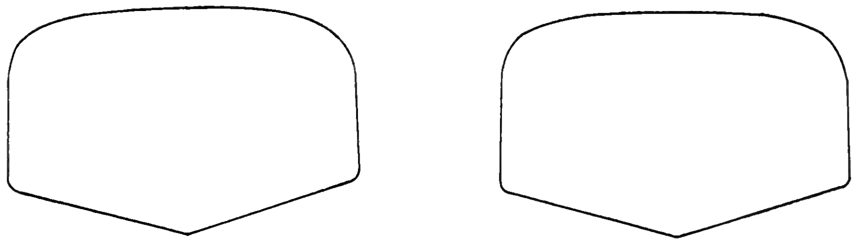
Gage 56-5/8" Gage 56-3/8"

M.P. 1444+ , CURVE NO. 710, DEGREE 4°59', Superelevation 5-1/4", Lubricated



Gage 56-3/8" Gage 56-1/4"

M.P. 1444+ , CURVE NO. 710, DEGREE 4°59', Superelevation 5-1/4", Lubricated



Tonnage to August 1, 1965 - 179,496,347 G.T.
Tonnage to August 1, 1967 - 219,958,636 G.T.

flaking areas, 1162-B17, C21 and E12. Apparently the small shell noted in rail 1162-B17 in 1964 had worn away. Most high-side rail ends were chipped to some degree, especially at the west end of the rails. A few low-side rail ends were chipped also. Several rails in the east end of the curve were badly burned by slipping wheels.

Of the comparative regular high-side rails in Curve No. 52, only rail 10257-B17 was found to contain very light flaking at mid-rail. High-side rail 10257-B14 was heavily chipped at the west end in the joint. A few additional high-side rails were chipped at the ends.

In September 1966, after 109,544,875 gross tons of traffic, 9 of the 66 high-silicon rails in the high side of Curve No. 48 contained very light flaking. No shelling or heavy flaking was noted. The ends of 14 high-side rails were chipped in the joints due to metal flow. Two low-side rails, 1162-F16 and 16191-F18 showed slight chipping of the head surface due to flow of the head metal toward the field side.

In the high side of Curve No. 52, very light flaking was noted in 7 of the 27 rails and the ends were chipped at the joints in 7 rails. No chipping of the head metal in the low side rails was observed.

By the time of the September 1967 inspection, after approximately 122,234,875 gross tons of traffic, the light flaking observed in the high-silicon rails in the high side of Curve No. 48 in 1965 had worn away and the gage corner of the rails appeared free of service developments. The slight chipping of the head surface due to flow in the two low-side rails had also about worn away.

The high-side rails in Curve No. 52 also appeared free of gage corner developments, the previously reported light flaking having worn away. However 9 of the 27 low-side rails showed some degree of crushing of the head metal toward the field side of the head.

There are no curve oilers near to these test curves so there is little or no evidence of lubrication in either installation.

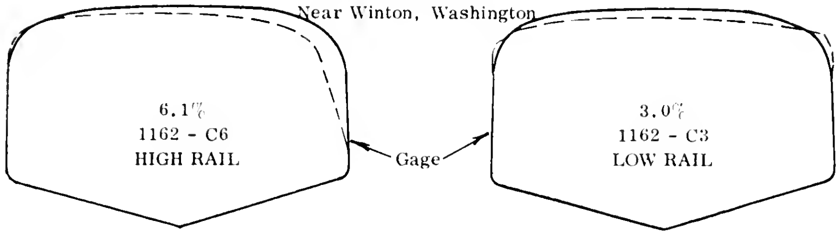
Contour tracings were made at each curve and are shown in Figs. 21 through 24.

FIGURE 21
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB HIGH SILICON

DIVISION Cascade

INSPECTION DATE 9-21-67

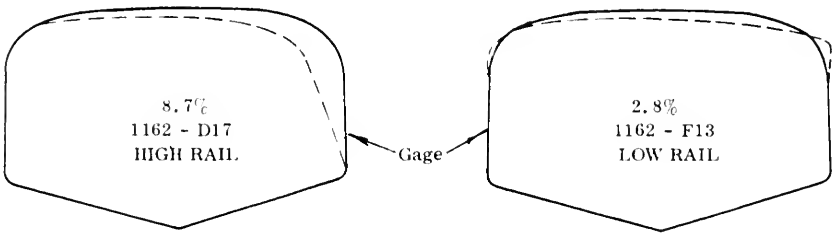
Laid June, 1955
Near Winton, Washington



Gage 56-3/4"

Gage 56-11/16"

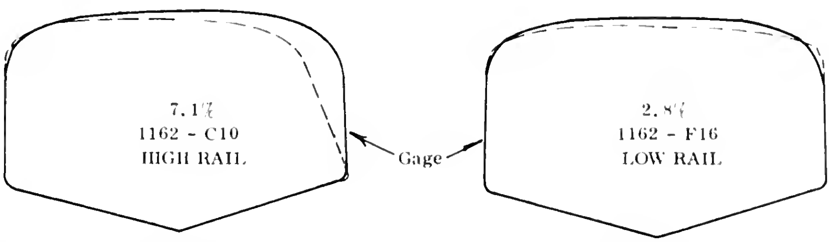
M.P. 1680+66, CURVE NO. 48, DEGREE 2°30'45", Superelevation 3.75", Not Lubricated



Gage 56-7/8"

Gage 57"

M.P. 1680+66, CURVE NO. 48, DEGREE 2°30'45", Superelevation 3.75", Not Lubricated



Gage 56-7/8"

Gage 57"

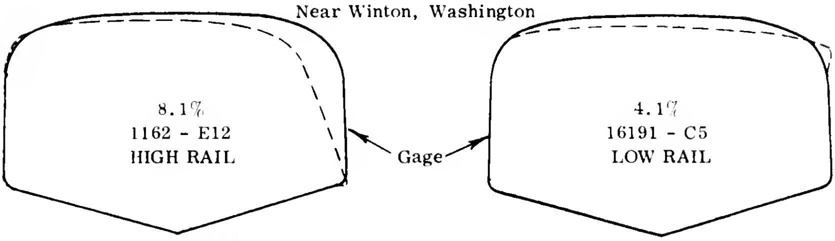
M.P. 1680+66, CURVE NO. 48, DEGREE 2°30'45", Superelevation 3.75", Not Lubricated

Tonnage to August 1, 1967, 122,234,875 G.T.

FIGURE 22
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB HIGH SILICON

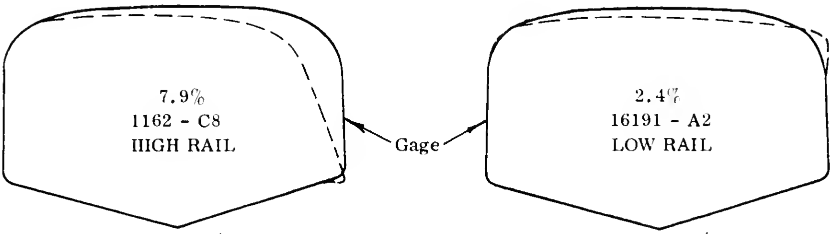
DIVISION Cascade INSPECTION DATE 9-21-67

Laid June, 1955
Near Winton, Washington



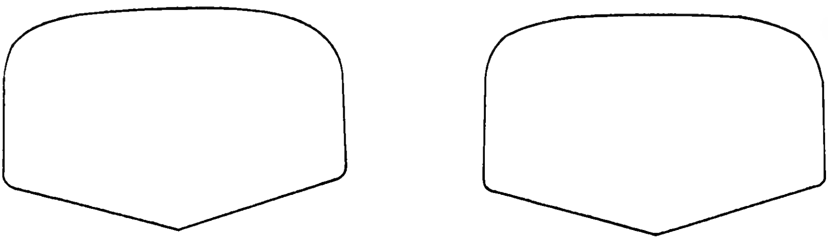
Gage 56-3/4" Gage 57"

M.P. 1680+91, CURVE NO. 48, DEGREE 2°30'45", Superelevation 3.75", Not Lubricated



Gage 57-1/8" Gage 56-7/8"

M.P. 1680+91, CURVE NO. 48, DEGREE 2°30'45", Superelevation 3.75", Not Lubricated



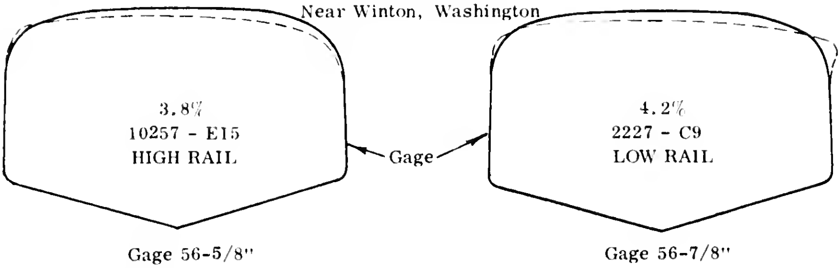
Tonnage to August 1, 1967 - 122,234,875 G.T.

FIGURE 23

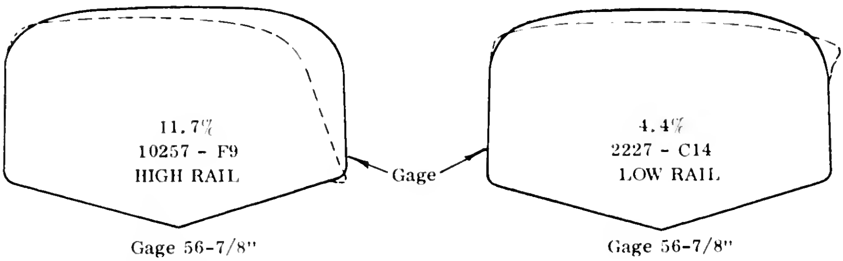
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB STD. CARBON

DIVISION Cascade INSPECTION DATE 9-21-67

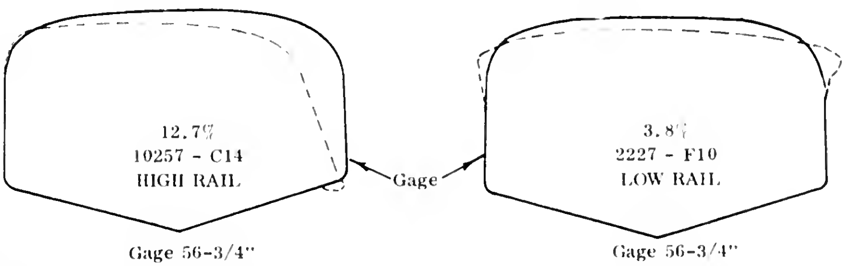
Laid June, 1955
Near Winton, Washington



M.P. 1683+33, CURVE NO. 52, DEGREE 2°30', Superelevation 2.5", Not Lubricated



M.P. 1683+33, CURVE NO. 52, DEGREE 2°30', Superelevation 2.5", Not Lubricated



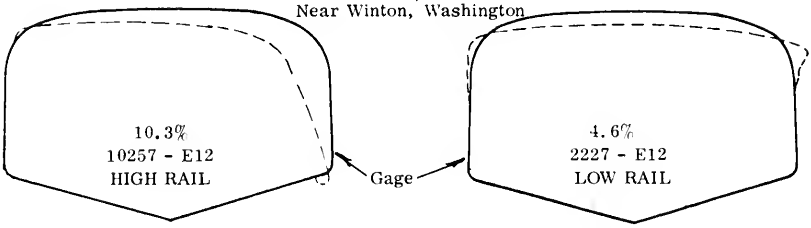
M.P. 1683+33, CURVE NO. 52, DEGREE 2°30', Superelevation 2.5", Not Lubricated

Tonnage to August 1, 1967 - 122,234,875 G.T.

FIGURE 24
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB STD. CARBON

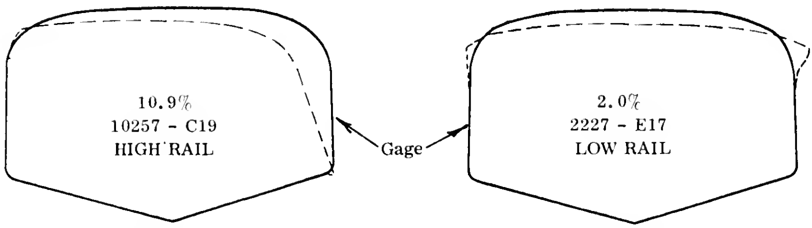
DIVISION Cascade INSPECTION DATE 9-21-67

Laid June, 1955
Near Winton, Washington



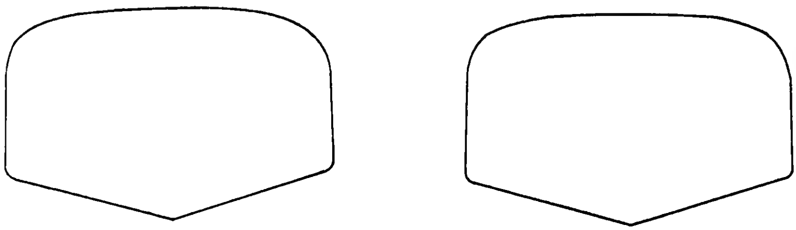
Gage 56-3/4" Gage 56-3/4"

M.P. 1683+39, CURVE NO. 52, DEGREE 2°30', Superelevation 2.5", Not Lubricated



Gage 56-7/8" Gage 56-15/16"

M.P. 1683+39, CURVE NO. 52, DEGREE 2°30', Superelevation 2.5", Not Lubricated



Tonnage to August 1, 1967 - 122,234,875 G.T.

Appendix 8b

Shelly Rail Investigation—Results of Rolling-Load and Slow-Bend Tests

A rail problem of major concern to the railroad industry is the resistance of rail to shelling. Two methods presently employed for improving this property are the addition of alloying elements and the heat treating of rail. The cradle-type rolling-load tests conducted at the Association of American Railroads Research Center are designed to evaluate these methods of improving the resistance to shelling. Rolling load test results obtained from these machines for the period between October 1, 1966 and October 1, 1967 are shown in Table 1.

The S-15 series was initiated at the request of the Southern Pacific Company to evaluate rail heat treated by the National Cylinder Gas (previously the Hammon process) flame-hardening process. Rolling-load test results for specimens S-15A through S-15W and S-15Y were reported last year and are included in this report for information. Specimens S-15W, S-15X, S-15E-2 and S-15F-2 are all secondhand 132-lb head-free rail heat treated to 3/16 in depth. Specimens S-15G-2 and S-15H-2 were not heat treated (secondhand 132-lb head-free rail) and used as control samples. A photograph of a transverse section cut from the end of specimen S-15X was etched in a 10 percent nital solution to show the heat pattern and is shown in Fig. 1. Specimens S-15Y, S-15Z, S-15A-2 and S-15B-2 were all new 136-lb CF&I rail heat treated to 3/16-in depth. Specimens S-15C-2 and S-15D-2 were not heat treated (new 136-lb CF&I rail) and used as control samples. A photograph of a transverse section cut from the end of specimen S-15Z was etched in a 10 percent nital solution to show the heat pattern and is shown in Fig. 2. Specimen S-15I-2 and S-15J-2 are new 136-lb CF&I rail heat treated to 3/16 in depth using a different heat-treating practice than that used to heat treat specimens S-15Y, S-15Z, S-15A-2 and S-15B-2. A photograph of a transverse section cut from the end of specimen S-15I-2 was etched in a 10 percent nital solution to show the heat pattern and is shown in Fig. 3. Specimens S-15K-2 and S-15L-2 are of secondhand 132-lb head-free rail heat treated to 3/16 in depth using a different heat treating practice than that used to heat-treat specimens S-15W, S-15X, S-15E-2 and S-15F-2. A photograph of a transverse section cut from the end of specimen S-15L-2 was etched in a 10 percent nital solution to show the heat pattern and is shown in Fig. 4.

Rolling-load tests previously conducted on flame-hardened rails produced by the Hammon process at its pilot plant in Oakland, Calif. showed satisfactory results. The flame-hardened rail specimens tested in the S-15 series were produced by N.C.G. (previously Hammon process) at its production installation at Tracy, Calif.

The S-16 series was initiated at the request of the Illinois Central Railroad to evaluate rail heat treated by the Linde process. A transverse section cut from the end of specimen S-16C, Fig. 5, was etched with a 10 percent nital solution and found to have a ½-in depth-hardened area.

All hardness checks shown on the photographs in this report were taken at 1/16-in intervals with a Rockwell Hardness tester using the "c" scale and converted to BHN readings.

During this period there were no slow bend tests conducted on rails at the Association of American Railroads Research Center.

TABLE 1
MECHANICAL PROPERTIES AND ROLLING LOAD TESTS
AAR Research Center, (October 1, 1966 to October 1, 1967)

Spec. No.	Size and Kind of Rail	Avg. Brin. Hard.	Cycles for Failure of 50,000 lb Wheel Load
S-15A	136 lb rail flame hardened to 3/8" depth by the Hammon process for the SP.		497,400
S-15B	136 lb rail flame hardened to 3/8" depth by the Hammon process for the SP.	250-352	476,400
S-15C	136 lb rail flame hardened to 5/16" depth by the Hammon process for the SP.	240-332	716,800
S-15D	136 lb rail flame hardened to 1/8" depth by the Hammon process for the SP.	255-372	2,586,700
S-15J	136 lb rail flame hardened to 3/16" depth by the Hammon process for the SP.	235-352	1,257,900
S-15K	136 lb rail flame hardened to 1/4" depth by the Hammon process for the SP.	240-342	622,600
S-15L	136 lb rail flame hardened to 9/16" depth by the Hammon process for the SP.	245-332	945,600
S-15M	136 lb rail from SP.		3,149,499 No shell
S-15N	136 lb rail flame hardened to 3/16" depth by the Hammon process for the SP.	245-352	1,619,200
S-15O	136 lb rail flame hardened to 3/16" depth by the Hammon process for the SP.	245-352	2,772,900
S-15P	*132 lb head free rail flame hardened to 1/4" depth by the Hammon process for the SP.	245-322	171,100
S-15Q	*132 lb head free rail flame hardened to 1/4" depth by the Hammon process for the SP.	245-322	311,600

TABLE 1
(Continued)
MECHANICAL PROPERTIES AND ROLLING LOAD TESTS
AAR Research Center, (October 1, 1966 to October 1, 1967)

Spec. No.	Size and Kind of Rail	Avg. Brin. Hard.	Cycles for Failure of 50,000 lb Wheel Load
S-15R	*132 lb head free rail flame hardened to 1/4" depth by the Hammon process for the SP.	245-313	282,500
S-15S	*132 lb head free rail flame hardened to 1/4" depth by the Hammon process for the SP	250-342	708,700
S-15U	136 lb rail flame hardened to 1/4" depth by the Hammon process for the SP.	250-342	446,900
S-15V	*132 lb head free rail flame hardened to 1/4" depth by the Hammon process for the SP.	250-352	636,400
S-15W	*132 lb head free rail flame hardened to 3/16" depth by the Hammon process for the SP.	255-332	818,400
S-15X	*132 lb head free rail flame hardened to 3/16" depth by the Hammon process for the SP.	255-342	482,300
S-15Y	136 lb rail flame hardened to 3/16" depth by the Hammon process for the SP.	260-352	441,600
S-15Z	136 lb rail flame hardened to 3/16" depth by the Hammon process for the SP.	255-362	461,400
S-15A-2	136 lb rail flame hardened to 3/16" depth by the Hammon process for the SP.		722,300
S-15B-2	136 lb rail flame hardened to 3/16" depth by the Hammon process for the SP.	260-352	809,100
S-15C-2	136 lb rail submitted by the SP.		1,570,700
S-15D-2	136 lb rail submitted by the SP.		2,402,400

TABLE 1
(Continued)
MECHANICAL PROPERTIES AND ROLLING LOAD TESTS
AAR Research Center, (October 1, 1966 to October 1, 1967)

Spec. No.	Size and Kind of Rail	Avg. Brin. Hard.	Cycles for Failure of 50,000 lb Wheel Load
S-15E-2	*132 lb head free rail flame hardened to 3/16" depth by the Hammon process for the SP.		660,300
S-15F-2	*132 lb head free rail flame hardened to 3/16" depth by the Hammon process for the SP.		603,000
S-15G-2	*132 lb head free rail submitted by the SP.		1,069,600
S-15H-2	*132 lb head free rail submitted by the SP.		1,225,900
S-15I-2	136 lb rail flame hardened to 3/16" depth by the Hammon process for the SP.	245-332	726,800
S-15J-2	136 lb rail flame hardened to 3/16" depth by the Hammon process for the SP.	255-332	917,900
S-15K-2	*132 lb head free rail flame hardened to 3/16" depth by the Hammon process for the SP.	245-313	832,500
S-15L-2	*132 lb head free rail flame hardened to 3/16" depth by the Hammon process for the SP.	240-322	587,400
S-16A	*115 lb RE rail flame hardened to 1/2" depth by the Linde process for the IC.		725,600
S-16B	*115 lb RE rail flame hardened to 1/2" depth by the Linde process for the IC.		1,764,600
S-16C	*115 lb RE rail flame hardened to 1/2" depth by the Linde process for the IC.	230-362	1,676,900

*Secondhand Rail

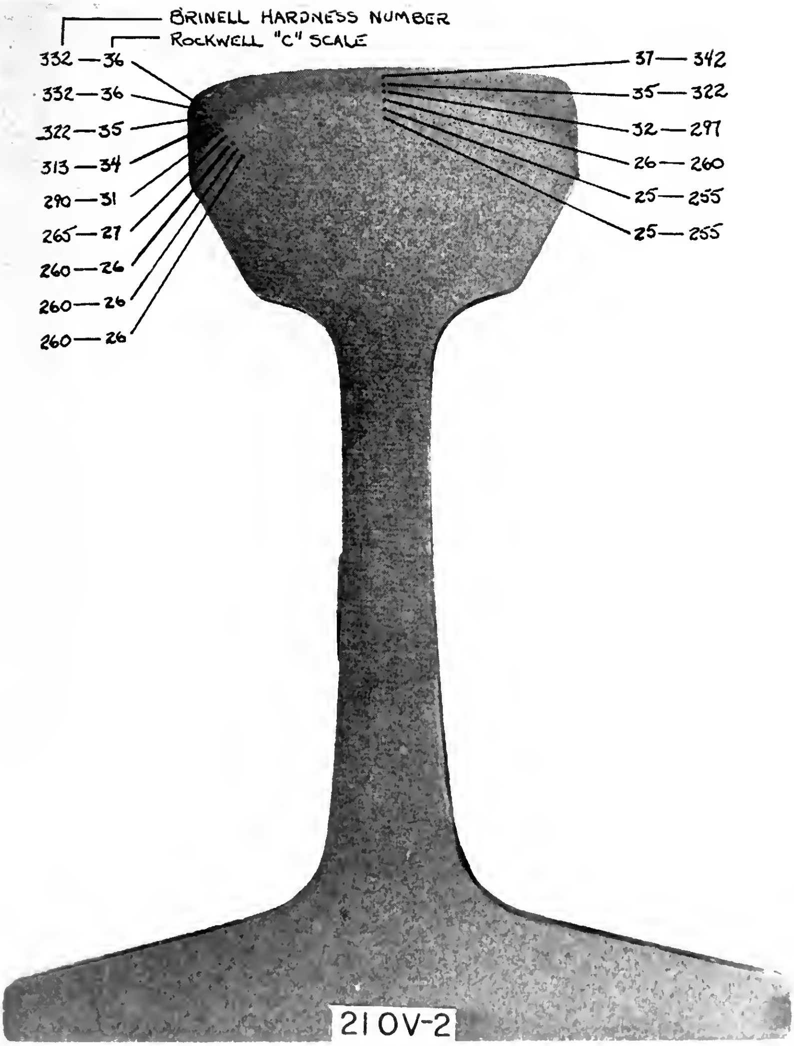


Fig. 1—View of a secondhand 132-lb H. F. rail, flame hardened by N. C. G. (previously the Hammon process) for the SP Co. This section, cut from the end of specimen S-15X, was etched with a 10 percent nital solution and found to have a hardened area 3/16 in deep. Hardness checks taken at 1/16-in intervals are shown in the above photograph. This specimen developed a shell after being subjected to 482,300 cycles in the cradle-type rolling-load machine.

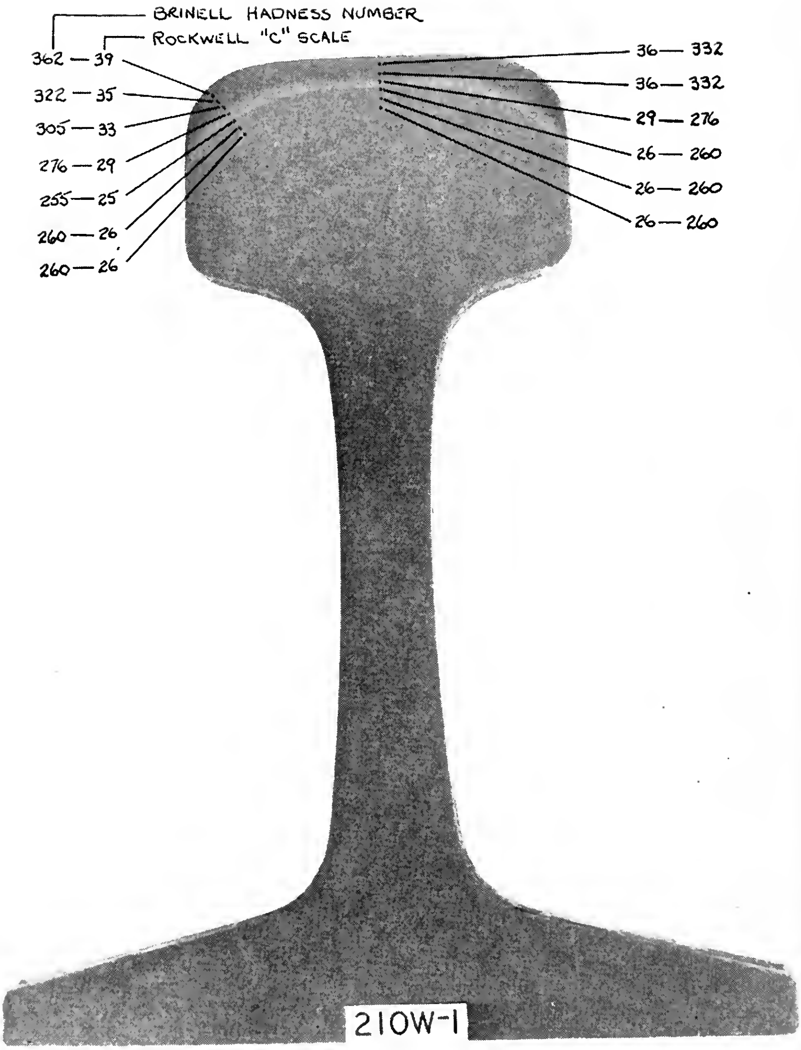


Fig. 2—View of a 136-lb CF&I rail, flame hardened by N.C.G. (previously the Hammon process) for the SP Co. This section, cut from the end of specimen S-15Z, was etched with a 10 percent nital solution and found to have a hardened area 3/16 in deep. Hardness checks taken at 1/16-in intervals are shown in the above photograph. This specimen developed a shell after being subjected to 461,400 cycles in the cradle-type rolling-load machine.

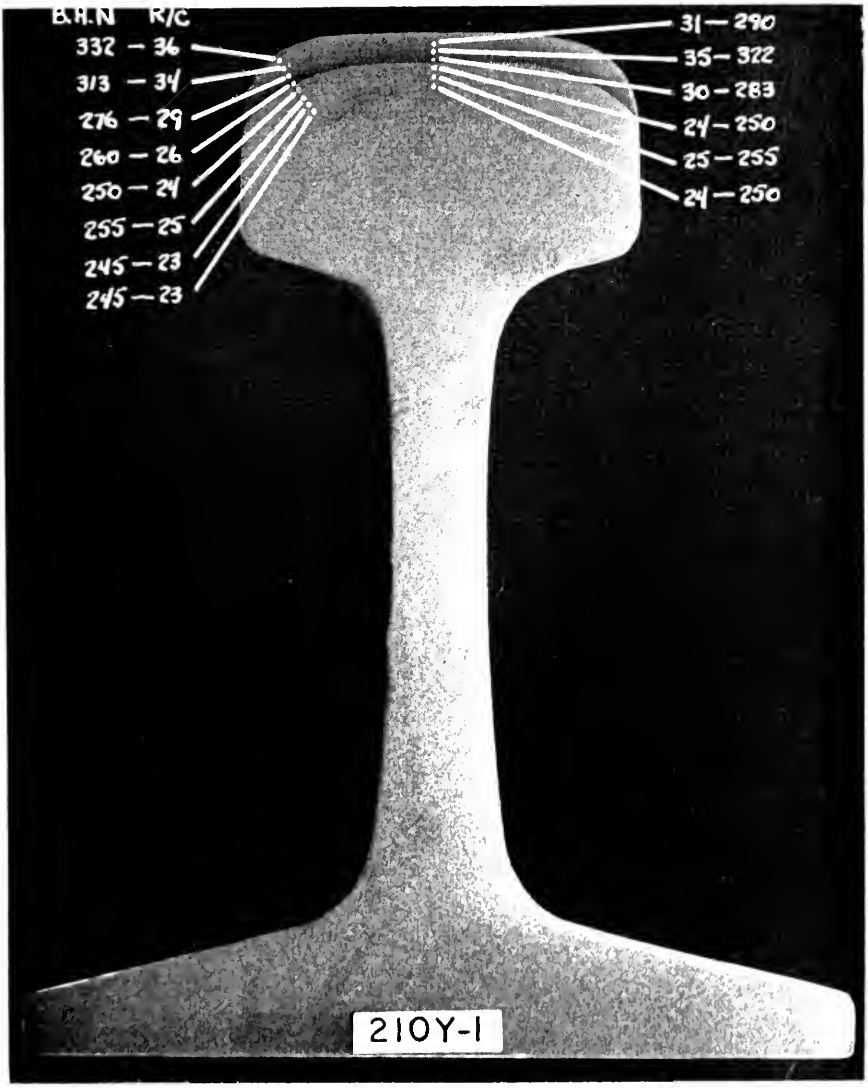


Fig. 3—View of a 136-lb CF&I rail, flame hardened by N.C.G. (previously the Hammon process) for the SP Co. This specimen, cut from the end of specimen S-151-2, was etched with a 10 percent nital solution and found to have a hardened area 3/16 in deep. Hardness checks taken at 1/16-in intervals are shown in the above photograph. This specimen developed a shell after being subjected to 726,800 cycles in the cradle-type rolling-load machine.

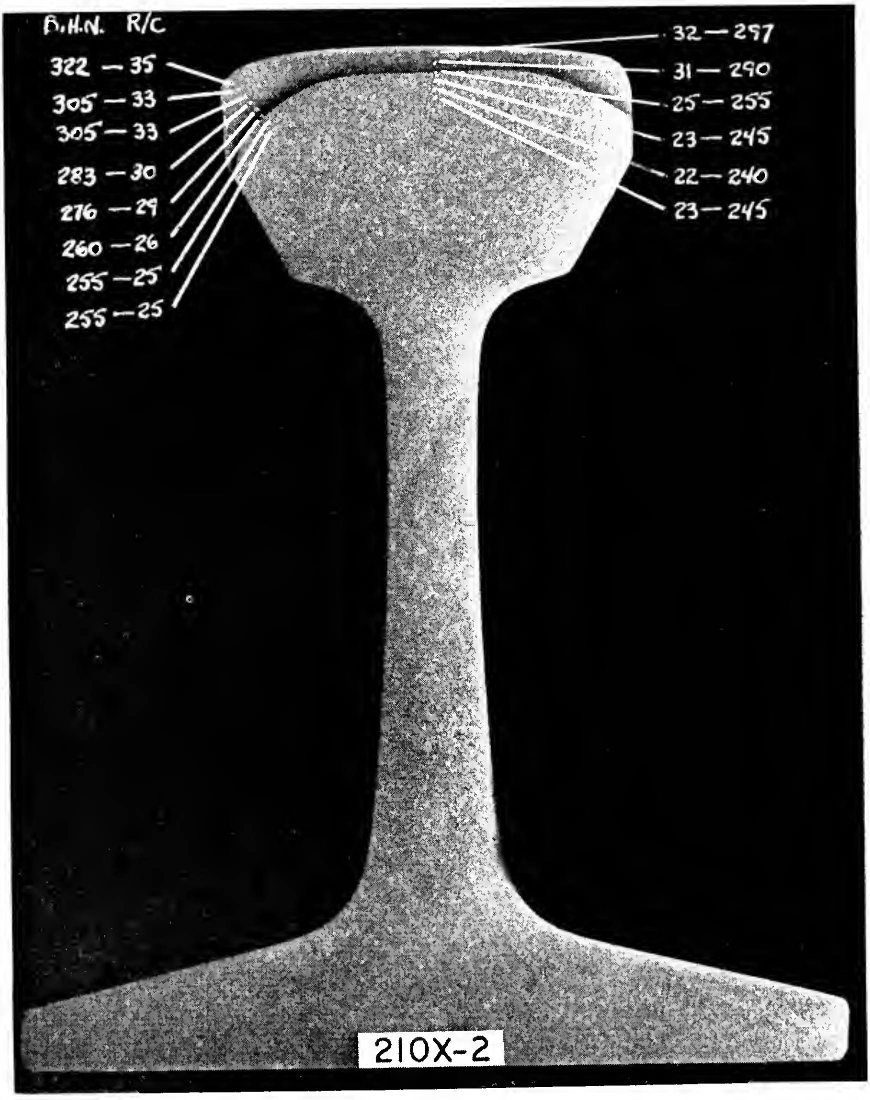


Fig. 4—View of a secondhand 132-lb H. F. rail, flame hardened by N.C.G. (previously the Hammon process) for the SP Co. This section, cut from the end of specimen S-15L-2, was etched with a 10 percent nital solution and found to have a hardened area 3/16 in deep. Hardness checks taken at 1/16-in intervals are shown in the above photograph. This specimen developed a shell after being subjected to 587,400 cycles in the cradle-type rolling-load machine.

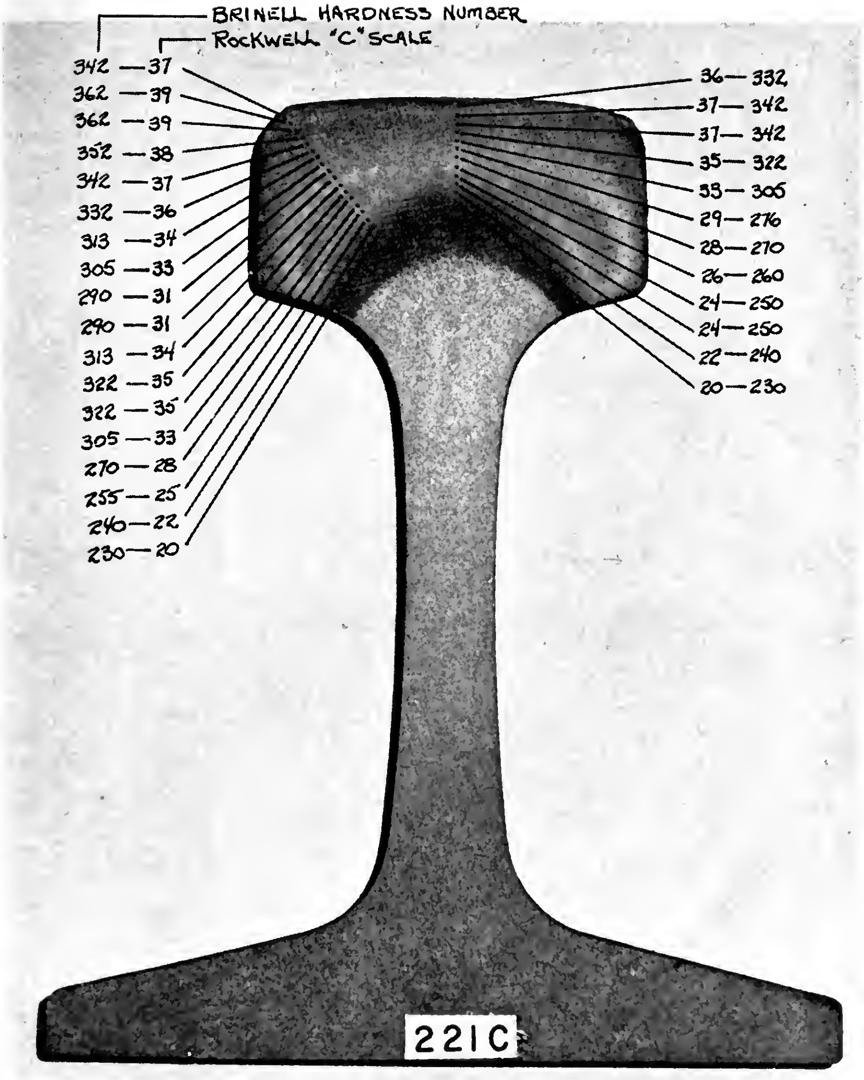


Fig. 5—View of secondhand 115-lb RE rail that was flame hardened by Linde for the Illinois Central Railroad. This section, cut from the end of specimen S-16C, was etched with a 10 percent nital solution and found to have a hardened area 1/2 in deep. Hardness checks taken at 1/16-in intervals are shown in the above photograph. This specimen developed a shell after being subjected to 1,676,900 cycles in the cradle-type rolling-load machine.

Report on Assignment 9

Standardization of Rail Sections

E. H. Waring (chairman, subcommittee), C. C. Herrick, J. B. Clark, C. E. Morgan, R. C. Postels, S. H. Barlow, A. N. Brauer, B. Bristow, R. D. Claborn, M. W. Clark, O. E. Fort, C. E. R. Haight, C. J. Henry, B. R. Meyers, G. L. P. Plow, J. M. Rankin, I. A. Reiner, D. H. Shoemaker, H. F. Smith.

During the past year Subcommittee 9 has secured from Canadian and United States rail mills a summary of the tonnage rolled in each rail section in 1966. A tabulation of that information is presented below.

Rail Rolled by Weight and Sections—1966

Weight	*Section*	*Tons Rolled*	*Percent of Total*
140*	AREA	45,040	4.37
136	NYC	15,204	1.47
136*	AREA	125,783	12.20
133	AREA	95,305	9.24
132*	AREA	156,443	15.17
131	AREA	3,229	0.31
130	AREA	4,757	0.46
130	REHF	293	0.03
130	PS	1,500	0.15
129	CB&Q	773	0.07
127	(DUDLEY)	600	0.06
122	CB	50,370	4.89
119*	CF&I	79,661	7.73
115*	AREA	299,277	29.03
112	AREA	1,975	0.19
106*	CF&I	490	0.05
105	DUDLEY	1,500	0.15
100	ARA-B	13,229	1.28
100	ARA-A	47,913	4.65
100*	AREA	17,385	1.69
100	PS	1,138	0.11
100	ASCE	5,932	0.58
100	REHF	12,190	1.18
100	(C&NW)	951	0.09
90*	ARA-A	20,848	2.02
90	ASCE	4,979	0.48
85	ASCE	8,886	0.86
85	CPR	8,921	0.87
80	ASCE	6,429	0.62
	TOTAL	1,031,001	100.00

*Sections listed on page 4-M-2 of the AREA Manual as those to which it is recommended that purchases of new rail be limited.

It is noted that 744,927 tons, or 72.25 percent of the total rail rolled in 1966, were in the sections to which it is recommended that purchases of new rail be limited.

This report is submitted as information.

Influence Chart for Moments in Railway Rails*

By G. C. MARTIN

ACKNOWLEDGMENT

The author wishes to express his sincere appreciation to William W. Hay, professor of railway civil engineering, University of Illinois, for his valuable advice, aid and guidance.

This research was made possible by the University of Illinois Research Board, which provided the funds for the use of the IBM 7094-1401 computer system in the Department of Computer Science of the University of Illinois, and by the Association of American Railroads, which provided the funds for preparation of the final report.

The cooperation of the Department of Civil Engineering of the University of Illinois is also appreciated for the use of its IBM 1620 computer system.

ABSTRACT

This report contains a graphical method of analysis for determining the moments in a railway rail. The method, based on a beam on an elastic foundation analysis, requires use of an influence chart and requires the wheel loading configuration under consideration to be drawn to a scale of 1 inch equals 1 foot and then be placed on the chart. Coefficients taken from the chart are then used to determine the moment at a given point in the rail. Changes in the track properties or finding the moment at another point in the rail are accomplished by changing the position of the scaled wheel loading configuration on the chart and noting new coefficients.

1. INTRODUCTION AND PURPOSE

The current method of determining moments in a railroad rail was presented in the "Progress Report of the Special Committee to Report on Stresses in Railroad Track" of the American Railway Engineering Association**. The method is based on a beam on an elastic foundation analysis and is implemented by calculating a number of parameters. Then through use of a "Master Diagram", moment coefficients are found which are in turn related to the moments in a rail. The method is briefly described later in this paper.

The purpose of this paper is to set forth a graphical method for determining moments in a rail. The method requires that the wheel loading configuration be drawn to a scale of 1 inch equals I foot and this scale drawing be placed on an "Influence Chart."

As will be seen, because of the graphical nature of this method, many calculations are automatically accomplished by changing the position of the scaled configuration on the chart whereas use of another method may necessitate many machine or hand computations to obtain the same results.

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* Study conducted by Railway Research Department of Civil Engineering, Engineering Experiment Station, University of Illinois, in cooperaton with the University of Illinois Research Board and the Association of American Railroads.

** Progress Report of the Special Committee to Report Stresses in Railroad Track—Vol. 19, Proceedings of the American Railway Engineering Association—pp. 875–1058.

2. CONVENTIONAL METHOD—MASTER DIAGRAM

The theory for finding moments in a rail is based on the solution of the differential equation for a beam on an elastic foundation. For a single wheel load, the solution for the moment, at a distance X from the load is:

$$M = P \sqrt[4]{\frac{EI}{64U}}\, e^{-X \sqrt[4]{\frac{U}{4EI}}} \left[\cos\left(X \sqrt[4]{\frac{U}{4EI}}\right) - \sin\left(X \sqrt[4]{\frac{U}{4EI}}\right)\right] \quad \text{.......... (1)}$$

For $X \geqq 0$

Where: P = wheel load in pounds
E = the modulus of elasticity of the rail
I = the moment of inertia of the rail
U = the modulus of rail support
X = the distance from the load P
e = base of natural logarithms = 2.7183

To find the total moment due to more than one load, the moment contribution for each load could be superimposed. Obviously, equation (1) must be applied once for each load. This would be cumbersome for hand computation. However, equation (1) may be expressed graphically in a "Master Diagram" so that the moment equation becomes $M = Mo \times C$

Where: $Mo = 0.318PX_1$

$$X_1 = \frac{\pi}{4} \sqrt[4]{\frac{4EI}{U}}$$

C = a coefficient taken from the Master Diagram
π = a constant = 3.1416

Fig. 1 shows the "Master Diagram". As an illustration of the use of this diagram, suppose one wished to calculate the moment at point A in Fig. 2, due to the wheel loading configuration shown in the figure.

The procedure would be as follows:

(1) calculate $X_1 = \frac{\pi}{4} \sqrt[4]{\frac{4EI}{U}}$
(2) calculate $Mo = 0.318\ P_1X_1$
(3) form the ratio X_2/X_1
(4) from the Master Diagram take the Relative Value of Bending Moment in Rail in terms of Mo (ordinate) for the abscissa found in (3)
(5) multiply the value in (4) by Mo
(6) repeat (2), (3), (4), (5), for X_3/X_1 and P_3
(7) repeat (2), (3), (4), (5), for X_4/X_1 and P_4
(8) step (5) in each case yields the moment contribution for the load under consideration. The sum of all moment contributions is the total moment. To find the moment at any other point, the above procedure is repeated using new values of X_2, X_3, and X_4.

3. GRAPHICAL METHOD—INFLUENCE CHART

If one glances back at equation (1), it will be observed that E, I, and U always appear as a ratio and never as separate entities. As E in most cases can be chosen equal to 30,000,000 psi, we can limit our discussion to the effect of I and U.

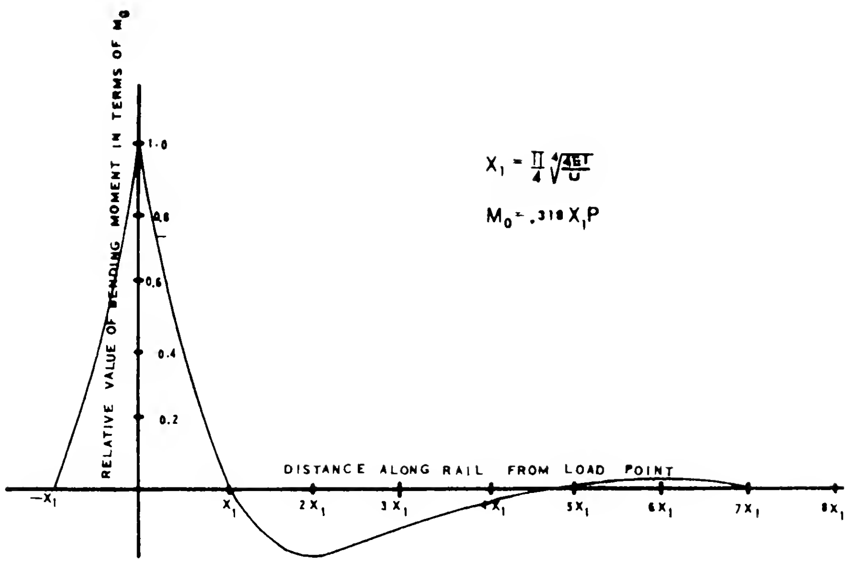


FIGURE 1 MASTER DIAGRAM MOMENT LINE

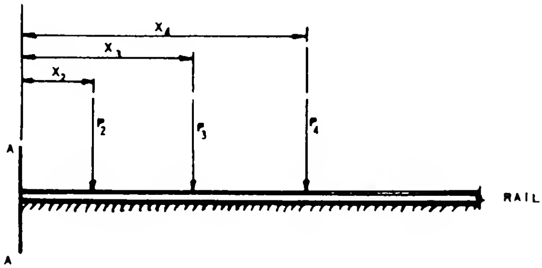


FIGURE 2 WHEEL LOADING CONFIGURATION

(As will be seen later, the effect caused by an E other than 30,000,000 psi does not cause loss of generality in the method to be presented).

Further, for most track conditions the ratio of I/U will be between 0.01 and 0.12. Again one should note that I/U always appears as a ratio in equation (1), and therefore the moment in a rail due to any wheel configuration is dependent only on this ratio, and not on a specific value of I or U. Thus, if both I and U are increased or decreased proportionately, the moment in the rail will remain the same.

Finally, one should observe from equation (1), that the moment caused by a wheel load at a distance greater than 20 ft from the wheel load becomes small.

Suppose now using $E = 30{,}000{,}000$ psi and $I/U = 0.12$ and $P = 1$ lb, the moment found for equation (1) is plotted as a function of the distance (in feet) from the load. The result is shown in Fig. 3. (One should note that the ordinate becomes an influence coefficient and the moment due to a load of P lb is just $P \times$ the influence coefficient.)

Similarly, suppose for $E = 30{,}000{,}000$ psi and $I/U = 0.01$ and $P = 1$ lb, equation (1) is again plotted. The result will be as seen in Fig. 4. Similar moment curves will occur for any other I/U between 0.01 and 0.12, $E = 30{,}000{,}000$ psi and $P = 1$ lb.

Now, instead of making many I/U graphs, suppose a three dimensional plot is made of the moment coefficient on the vertical axis, X, the distance from the load on one horizontal axis and I/U on the other horizontal axis. The result is shown in Fig. 5.

Now suppose that a line is drawn through all points whose values are 15, 10, 5, 0, − 1, − 2, − 3; this is also shown in Fig. 5. Finally, if these lines are projected on a horizontal plane as shown in Fig. 6, the projection becomes an "Influence Chart for Moments."

An influence chart visualized in the above manner accompanies this report. A description of the generation of the chart in mathematical terms may be found in the Appendix. The use of the chart requires that the I/U ratio be calculated and the wheel loading configuration scaled 1 inch equals 1 foot. The moment at some point X on the scaled wheel configuration diagram is found by laying the point X over the I/U value so that the diagram is perpendicular to the I/U axis at the I/U value under consideration. The moment coefficient value for each load is the value on the chart at the load in the scaled diagram. The total moment is the sum of load influence coefficient times the corresponding load described above.

One will note that once the wheel configuration has been scaled the computation will involve one division to calculate I/U and then one multiplication for each wheel load and one final summation to find the moment at any point. Finding the moments at other positions under the wheel loading configuration or at other value of I/U requires only a sliding of the scaled wheel configuration on the chart and repeating the above calculations.

4. AN EXAMPLE

For an illustration, suppose the moments under the wheel load P_1 and at "A" of the wheel configuration shown in Fig. 7 are to be calculated using the influence chart for a 132-lb rail ($I = 88.2$ in.⁴), E of 30,000,000 psi, and U equal to 2000 lb/in./in. The ratio I/U is then $\frac{88.2}{2000} = 0.0441$. To find the moment under P_1 the wheel load would then be scaled 1 inch equals 1 foot and then the scale configuration would be placed on the influence chart as shown in Fig. 8.

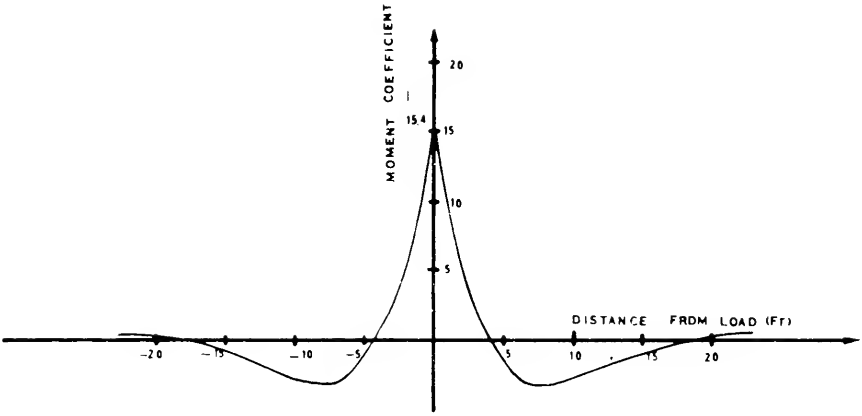


FIGURE 3 MOMENT INFLUENCE LINE FOR $\frac{I}{U} = 0.12$

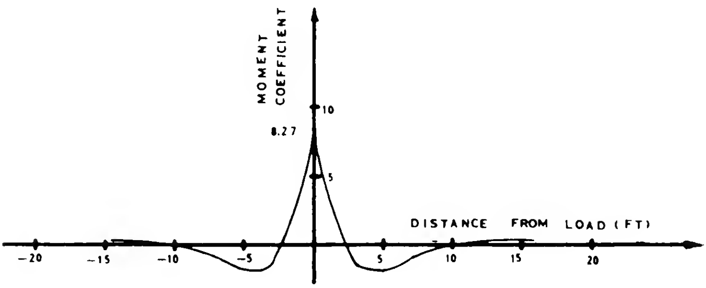


FIGURE 4 MOMENT INFLUENCE LINE FOR $\frac{I}{U} = 0.01$

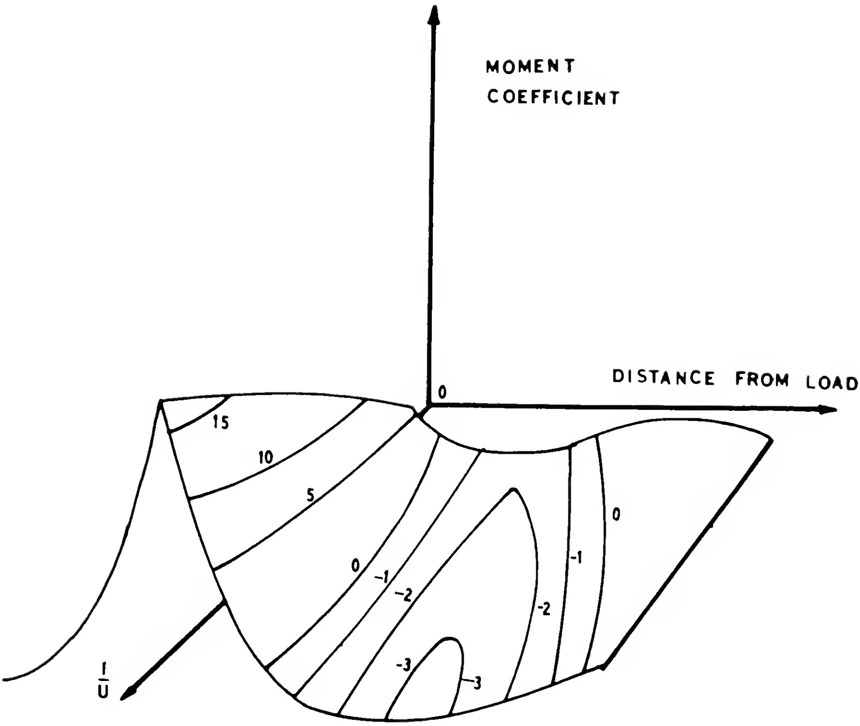


FIGURE 5 MOMENT INFLUENCE SURFACE

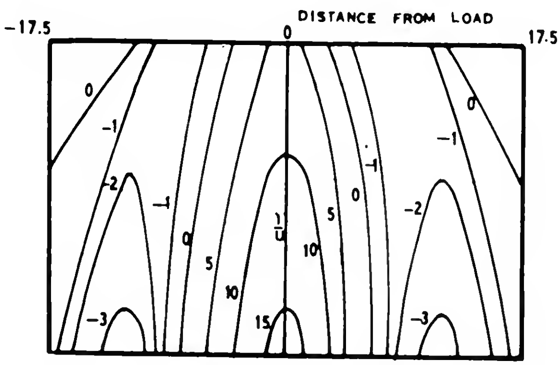


FIGURE 6 MOMENT INFLUENCE CHART

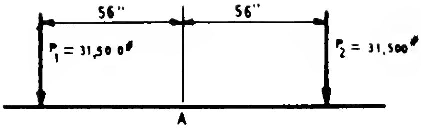


FIGURE 7 WHEEL LOADING CONFIGURATION

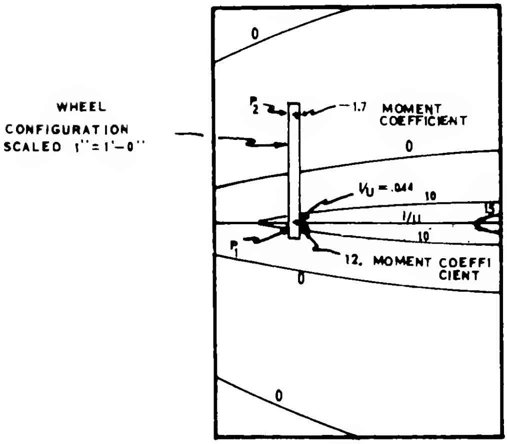


FIGURE 8 FINDING MOMENT COEFFICIENTS FOR MOMENT UNDER P_1

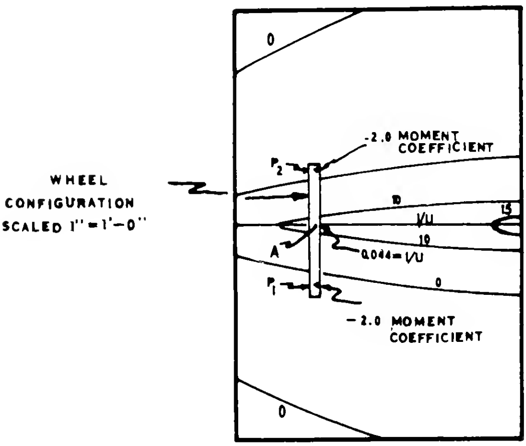


FIGURE 9 FINDING MOMENT COEFFICIENTS FOR MOMENT AT A

The moment coefficient taken from the chart for P_1 is 12.0 and for P_2 is -1.7. The total moment therefore is $12.0 \times 31{,}500 + (-1.7) \times 31{,}500 = 324{,}450$ in-lb. (The actual solution when run on a computer = 326,014 in-lb.)

To find the moment under "A" the scaled wheel loading configuration is then placed as shown in Fig. 9. The coefficients taken from the chart are for $P_1 = -2.0$ and $P_2 = -2.0$. The total moment is therefore $(-2.0) \times 31{,}500 + (-2.0) \times 31{,}500 = -126{,}000$ in-lb. (Actual solution when run on a computer = $-123{,}954$ in-lb.)

5. VARIATION IN E

The influence chart was developed for an $E = 30{,}000{,}000$ psi. The question remains as to how the chart may be used if E was of a value other then 30,000,000 psi. A glance back at equation (1) shows that E always appears as a ratio with I and U, i.e., EI/U or U/EI. Therefore to use the influence chart for a value of E other than 30,000,000, say E_1, the I/U ratio should be modified to $\frac{E_1}{30{,}000{,}000} \times \frac{I}{U}$. This new modified ratio would then be used as the I/U ratio on the influence chart. For instance, if in the previous example suppose E_1 was chosen to be 29,000,000 psi, then instead of referring to the I/U value of 0.0441 on the influence chart, the scaled wheel configuration should be placed at the I/U value of $\frac{29{,}000{,}000}{30{,}000{,}000} \times 0.0441 = 0.0426$.

6. ERRORS

The influence chart only shows values for the moment coefficient 17.5 ft from the Axis A-A. The question then arises as to the magnitude of the coefficients which lie off the influence chart. The maximum value of the influence coefficient off the chart is less than 0.13 for I/U less than 0.07. For $I/U = 0.12$ the maximum coefficient not shown is 0.32; however, beyond 20 ft from A-A the maximum coefficient is less than 0.14. In any case, these coefficients become relatively small and, except in very unusual circumstances, the effect of a wheel loading extending beyond the chart will be of minor consequence. As for other errors which arise because of the graphical procedure, one should assume that the method yields only two significant figures.

7. SUMMARY

This paper presents a graphical method of finding moments in a railroad rail arising out of the beam on an elastic foundation analysis. The method itself requires use of scaled wheel loading configuration, the accompanying influence chart and a few simple computations. An example is then presented as an illustration.

APPENDIX

GENERATION OF THE INFLUENCE CHART FOR MOMENTS IN RAILWAY RAILS

In an earlier section, it was stated that a three dimensional surface could be generated which described the variation of X, I/U and M in equation (1) when $P = 1$ lb and $E = 30{,}000{,}000$ psi. Lines could then be drawn through points of equal value on the surface and then these lines projected onto a horizontal plane. The projection became an influence chart for moments. The question now arises as to how the chart can be (and was) realized in more mathematical terms.

First one should note that the chart must be symmetric about the I/U axis. One can see this either physically or by means of equation (1). Thus the remaining discussion can focus on the development of one-half of the chart and the remainder of the chart can be developed by symmetry.

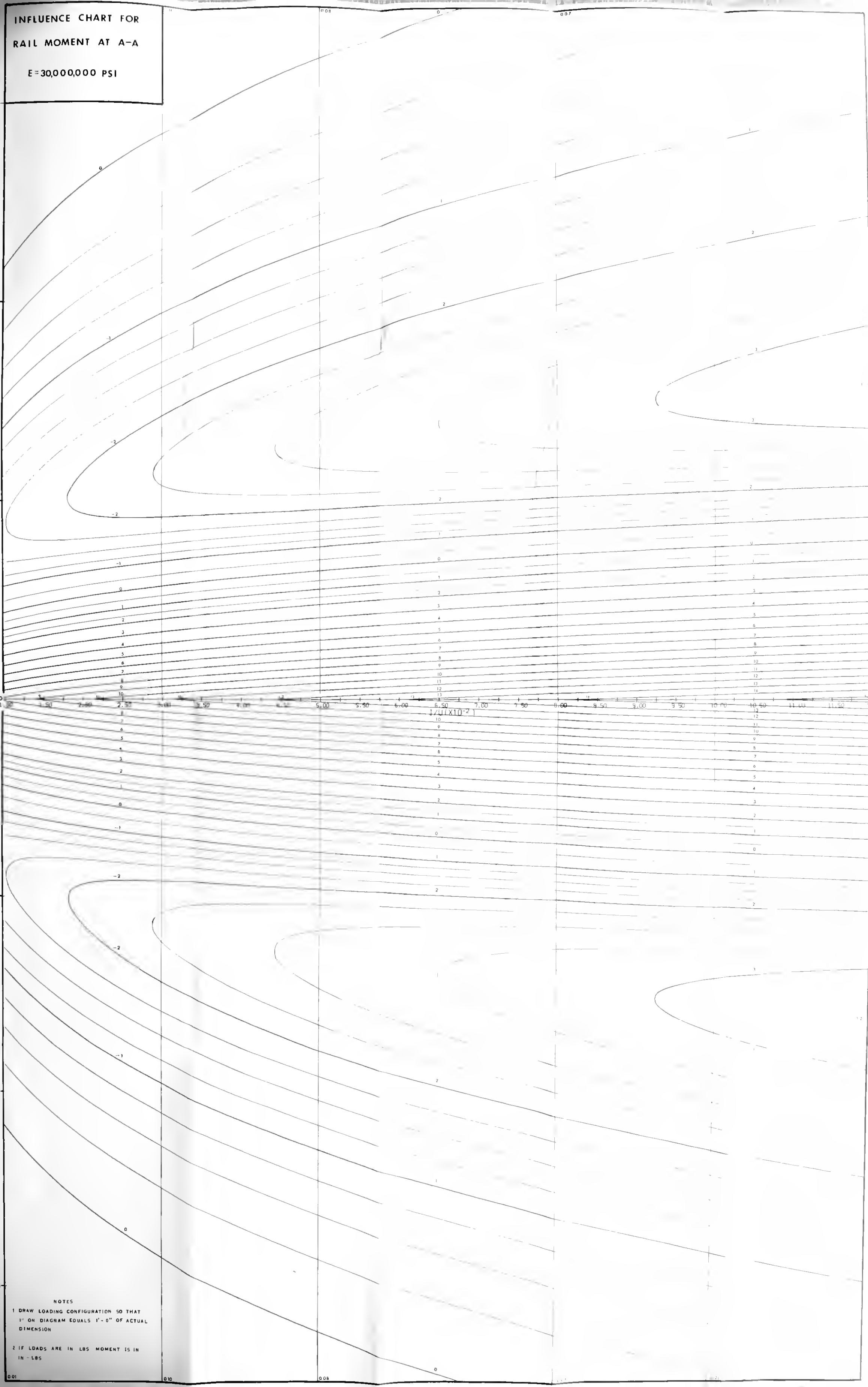
Secondly, if P is set equal to 1 lb in equation (1), values then derived from the equation become influence coefficients. The moment due to a load of P lb is then just P times the influence coefficient. Since the chart is based on a P of 1 lb and an E of 30,000,000 psi, the remaining discussion will assume the use of these values. In this light, M and the term "influence coefficient" are equal so they are used synonymously in the following discussion.

Bearing in mind the above preliminary remarks, the development of the influence chart is not difficult. Every line on the influence chart is a plot of X as the ordinate and the I/U ratio as the abscissa for "discrete" values of M, using $P = 1$ lb and $E = 30{,}000{,}000$ psi. The "discrete" values of M were chosen from 15.0 to -3.0, as these values were the range of the maximum and minimum values of the influence coefficients, for I/U between 0.01 and 0.12.

In the computer program, M and I/U were specified in equation (1) and then X was found by "Newton's Method." (Newton's Method is a procedure for solving an equation. One "guesses" at a solution and then applies the procedure. The procedure is an iterative process which converges to the "true" solution. A description of Newton's Method may be found in many books on analytical geometry and calculus.) However, when setting equation (1) equal to a discrete value of M and solving for X, a good guess for the starting value in Newton's Method should be made. This is because of the oscillatory nature of equation (1), and if a good initial starting value is not chosen, the method may converge to an erroneous value. (For example, there are theoretically an infinite number of X's for $M = 0.0$, but for the influence chart one is only interested in those X values less than 17.5 ft. One must therefore choose starting values so that "true" rather than erroneous values are found.) Finding good starting values is not a difficult task if one knows the shape of the function with which one is dealing. In the case under consideration, good starting values were found by making plots of M versus X for a given I/U.

The computer program itself started by assuming an $I/U = 0.12$ (and $E = 30{,}000{,}000$ psi, $P = 1$ lb) in equation (1). Then it read an M and a starting value for X in Newton's Method. Newton's Method was then initiated by the program which caused X to converge to a "true" value. The value for X and $I/U = 0.12$ was stored and then I/U was decremented by 0.0001. The X found in the $I/U = 0.12$ case was then used as a starting value in Newton's Method for the $I/U = 0.12 - 0.0001 = 0.1199$ case. Another "true" X was found and it was stored along with its corresponding I/U (i.e., $I/U = 0.1199$). The process whereby I/U is decremented, a starting value for X chosen to be the X value from the preceeding case, Newton's Method applied to find a "true" value and then storing the X and corresponding I/U value, was continued until I/U was decremented to 0.01, or if the M did not exist at the I/U under consideration. (For example, when M equals 5 the process stops when I/U reaches 0.01. On the other hand, however, when M equals 15 the procedure terminates at an I/U of about 0.11.)

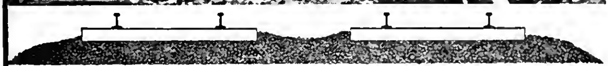
Once the procedure had terminated, the stored arrays, i.e. the X and the I/U arrays, were plotted using the X 's and the I/U 's as coordinates. The plot became a line on the influence chart. Its mirror image was then plotted as the chart is symmetrical. Finally, a new M and starting value for X was read, I/U set equal to 0.12 and the entire procedure restarted to yield another line. Lines were continually generated until there were no more M's to be read.



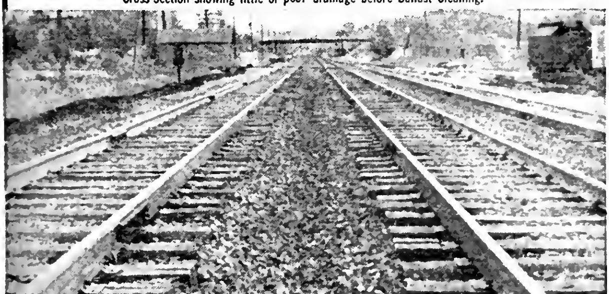
INFLUENCE CHART FOR
RAIL MOMENT AT A–A
E = 30,000,000 PSI
DISTANCE FROM LOAD TO A–A (FEET)
DISTANCE FROM LOAD TO A A (FEET)
1/U (X10⁻²)
A
A
NOTES
1 DRAW LOADING CONFIGURATION SO THAT 1" ON DIAGRAM EQUALS 1'-0" OF ACTUAL DIMENSION
2 IF LOADS ARE IN LBS MOMENT IS IN IN-LBS

ECONOMICAL TRACK DRAINAGE

WITH SPENO Ballast Cleaning



Cross-Section showing little or poor drainage before Ballast Cleaning.



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American Railway Engineering Association—Bulletin

Bulletin 614 June–July 1968
Proceedings Vol. 69*

CONVENTION ISSUE

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Sr. Vice President
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A. B. HILLMAN, JR
Treasurer
Chief Engr.
Belt Ry. of Chicago

EARL W. HODGKINS
Executive Secretary

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1965–68
Chief Engr.
N. P. Ry.

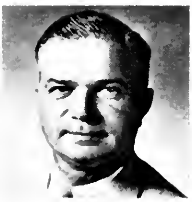
M. S. Reid
1965–68
Asst. Chief Engr. Maint.
C.&N.W. Ry.

J. B. Clark
1965–68
Chief Engr.
L.&N. Ry.

J. A. Rust
1965–68
Sr. Asst. Chief Engr.
Southern Ry.

G. V. Guerin
1966–69
Chief Engr.
G. N. Ry.

C. Neufeld
1966–69
Asst. Chief Engr.
C. P. Ry.



H. W. Kellogg
1966–69
Reg. Asst. Chief Engr.
C.&O. Ry.-B.&O. RR.

F. H. McGuigan
1966–69
Engr. Const.
M.P. RR.

E. Q. Johnson
1967–70
Chief Engr.
N.&W. Ry.

R. M. Brown
1967–70
Chief Engr.
U P RR

J. M. Salmon, Jr.
1967–70
Chief Engr.
Clinchfield RR

E. H. Waring
1967–70
Chief Engr.
D &R G W RR

PROGRAM

Sixty-Seventh Annual Convention

Palmer House, Chicago

March 19–21, 1968

Tuesday, March 19

Red Lacquer Room—9:30 am to 12:00 noon

Invocation—Dr. Kenneth Hildebrand, Pastor, Central Church of Chicago.

Recognition of speaker's table guests.

Presidential Address—T. B. Hutcheson, Assistant Vice President—Engineering and Maintenance of Way, Seaboard Coast Line Railroad.

Report of Executive Secretary—Earl W. Hodgkins.

Report of Treasurer—A. B. Hillman, Jr., Chief Engineer, Belt Railway Company of Chicago.

Greetings from the Railway Engineering-Maintenance Suppliers Association—H. R. Miller, President.

Keynote Address—R. R. Manion, Vice President, Operations and Maintenance Department, AAR.

Address—Railroad Engineering from a New Vantage Point, by A. Scheffer Lang, Federal Railroad Administrator, U. S. Department of Transportation.

Address—BART: A Progress Report (Illustrated), by B. R. Stokes, General Manager, Bay Area Rapid Transit District.

Red Lacquer Room—1:30 pm to 5:00 pm

Reports of Committees	Bulletin Numbers
18—Electricity (1:30)	610
20—Contract Forms (1:30)	609
Address (sponsored jointly by Committees 18 and 20)—High-Speed Passenger Service in the Northeast Corridor (Illustrated), by J. W. Diffenderfer, Assistant Vice President, Special Services, Pennsylvania New York Central Transportation Company.	
32—Systems Engineering (2:25)	610
13—Environmental Engineering (2:40)	609

Reports of Committees	Bulletin Numbers
9—Highways (3:00)	609
Address—Factors Influencing Safety at Highway—Railway Grade Crossings—A Summary of Recent Research (Illustrated), by H. L. Michael, Associate Director, Joint Highway Research Project, and Professor of Highway Engineering, Purdue University.	
16—Economics of Railway Location and Operation (3:45)	609
25—Waterways and Harbors (4:15)	610
Motion Picture on Container Handling at Ports—Today the 21st, produced by the Port of New York Authority.	

Wednesday, March 20

Red Lacquer Room—9:00 am to 11:50 am

28—Clearances (9:00)	610
Panel Discussion—Clearances and Problems Involved in Computerizing Them (Illustrated). Panel Members: Dr. H. N. Laden, Director of Research Services, Chesapeake & Ohio Railway—Baltimore & Ohio Railroad; D. H. Shoemaker, Chief Engineer, Northern Pacific Railway; D. E. Harmon, Systems Research Officer, Southern Railway; and R. H. Knittle, Assistant Engineer, Atchison, Topeka & Santa Fe Railway.	
15—Iron and Steel Structures (9:55)	611
7—Wood Bridges and Trestles (10:10)	611
Address—The Future of Timber in Railroad Bridges (Illustrated), by M. J. Rhude, Chairman, Research Committee, American Institute of Timber Construction; Director of Timber Construction, Koppers Company.	
30—Impact and Bridge Stresses (10:50)	611
24—Cooperative Relations with Universities (11:05)	610
Address—Goals of Engineering Education (Illustrated), by Dr. G. A. Hawkins, Vice President for Academic Affairs, Purdue University.	

ANNUAL LUNCHEON

Grand Ballroom—12:00 noon

Presentation of those at speaker's table.

Presentation of those at chairmen's table.

Announcement of results of election of officers.

Address—The Anatomy of a Railroad Merger, by W. Thomas Rice, President and Chief Executive Officer, Seaboard Coast Line Railroad.

Red Lacquer Room—2:00 pm to 5:00 pm

14—Yards and Terminals (2:00) 609
Address—The Fabricated Steel Erection Problems Incident to the Redevelopment of Penn Station in New York (Illustrated), by J. A. Sterner, Project Manager, Bethlehem Steel Corporation.

6—Buildings (2:40) 611

8—Masonry (3:10) 611
Address—Admixtures for Concrete (Illustrated), by A. K. Howe, Chief Engineer, Sika Chemical Corporation.

27—Maintenance of Way Work Equipment (3:50) 610

22—Economics of Railway Labor (4:05) 609
Address—The Design and Construction of A. E. Perlman Yard (Illustrated), by C. T. Popma, Assistant Vice President—Engineering, Pennsylvania New York Central Transportation Company.

Thursday, March 21

Red Lacquer Room—9:00 am to 12:10 pm

31—Continuous Welded Rail (9:00) 612
Address—Thermite Welding Practices of Rail in the United States (Illustrated), by K. H. Kannowski, Research Engineer, Illinois Central Railroad.

4—Rail (9:35) 612

3—Ties and Wood Preservation (9:55) 612

1—Roadway and Ballast (10:25) 612
Address—Stress Distribution in Track Structure (Illustrated), by R. M. Hardy, Dean of Engineering, University of Alberta.

5—Track (11:10) 612

11—Engineering and Valuation Records (11:25) 610
Motion Picture—Construction of D&RGW Line Change, Including Negotiations Between Railroad and Governmental Agencies, with introductory remarks by J. B. Byars, Assistant to Chief Engineer, Denver & Rio Grande Western Railroad.

Closing Business Session (12:10)
Installation of Officers.
Adjournment.

Nominating Committee—1968 Election

Past Presidents	*Elected Members*
L. A. Loggins, *Chairman* Retired Chief Engr., S. P. Co., T. & L. Lines	D. V. Sartore Chief Engr., Burl. Lines
R. H. Beeder Chief Engr. Sys., A.T. & S.F. Ry.	C. W. Wagner Engr. of Tests, C.N. Rys.
T. F. Burris Retired Gen. Mgr., C. & M.W., C.&O. Ry.–B.&.O. RR.	J. R. Williams Engr. of Brdgs., C.R.I. & P. RR.
A. V. Johnston Chief Engr., C.N. Rys.	R. G. Garland Engr. of Track, A.T. & S.F. Ry.
J. M. Trissal Vice Pres., R.E. & D., I. C. RR.	B. J. Worley Vice Pres.–Chief Engr., C.M. St.P. & P. RR.

The foregoing committee, which is composed of the five latest living past presidents of the Association and five elected members of the Association who are not past presidents, formulated their official slate of nominations at a meeting in Chicago on October 11, 1968, which nominations were presented to letter ballot vote of the membership with the January–February 1968 issue of the *AREA News*.

Committee of Tellers—1968 Election

The following committee was appointed to canvass the ballots for officers and directors and for members of the Nominating Committee, the count being made on March 20, 1968:

R. E. Pearson, Chairman	J. M. Helm	D. J. Moody
R. W. Tipper, Vice Chairman	W. R. Hyma	J. A. Naylor
	F. M. Jones	C. E. Peterson
W. F. Arksey	R. E. Kuston	L. L. Rekuch
L. R. Beattie	G. W. Mahn	R. F. Spars
S. W. Brunner	C. J. McConaughy	W. S. Stokely
W. F. Burt	L. E. McCullough	N. E. Whitney
J. J. Dwyer	G. N. McLennan	J. J. Williams

Successful Candidates in 1968 Election of Officers and Members of Nominating Committee

For President:

H. E. Wilson, Assistant Chief Engineer System, Atchison, Topeka & Santa Fe Railway, Chicago.

*For Senior Vice President:**

H. M. Williamson, Chief Engineer System, Southern Pacific Company, San Francisco, Calif.

For Junior Vice President:

J. B. Clark, Chief Engineer, Louisville & Nashville Railroad, Louisville, Ky.

For Directors:

East:

J. F. Piper, Chief Engineer—Maintenance, Penn Central Company, Philadelphia, Pa.

C. T. Popma, Assistant Vice President—Engineering, Penn Central Company, New York.

South:

S. A. Cooper, Chief Engineer, Gulf, Mobile & Ohio Railroad, Mobile, Ala.

West:

D. V. Sartore, Chief Engineer, Burlington Lines, Chicago.

For Members of the 1969 Nominating Committee:

East:

C. C. Herrick, Engineer Track Maintenance, Penn Central Company, New York.

South:

C. E. Weller, Engineer Maintenance of Way, Illinois Central Railroad, Chicago.

West:

B. J. Worley, Vice President–Chief Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Chicago.

Canada:

John Fox, Assistant Engineer of Track, Canadian Pacific Railway, Montreal, Que.

At Large:

O. E. Fort, Chief Engineer, St. Louis–San Francisco Railway, Springfield, Mo.

* Under the provisions of the Constitution, H. M. Williamson advances automatically from junior vice president to senior vice president.

PROCEEDINGS

Running Report of the 67th Annual Convention of the American Railway Engineering Association and Concurrent Annual Meeting of the Engineering Division, Association of American Railroads, March 19–21, 1968, Palmer House, Chicago, Including Committee Presentations, Specific Papers and Other Official Business of the Association and Division

Opening Session, March 19, 1968

President T. B. Hutcheson* Presiding

(The opening session of the 67th Annual Convention convened at 9:30 am.)

President Hutcheson: Members of the American Railway Engineering Association and guests: Welcome to the Sixty-Seventh Annual Convention of the American Railway Engineering Association and the concurrent 1968 Annual Meeting of the Engineering Division of the Association of American Railroads. Before we begin our busy two-and-a-half day schedule of work and deliberations, it is appropriate that we ask for divine guidance and assistance in our work. Dr. Kenneth Hildebrand, Pastor of the Central Church of Chicago, will give the invocation.

Invocation

Dr. Kenneth Hildebrand: Let us unite our hearts in prayer.

Almighty and ever gracious God who hath brought us to this hour, we thank Thee for the common interest, the deep concerns and the lasting friendships which bring together those who are gathered here this day.

Hear now the voice of one who expresses the hopes and longings of all. Stimulate them to know God, to lift their eyes to far horizons. The best bridges have not yet been built, the best track laid, the finest and most creative thinking has not been done. Grant them, therefore, the inquiring mind and the learning heart.

Give them a divine sense of discontent that is intolerant of the shoddy and even of the acceptable. Tear them loose from whatever may bind their vision and narrow their souls. Afflict them if they are too comfortable and comfort them if they are afflicted. Hold them steady when the grade is steep and the curves dangerous and the power low. Grant them the courage to despise the shortcut and the easy way.

Oh God, may the responsibility heat them up and not grind them down, and when troubles seek them out, grant them confidence in themselves and a steadfast faith in Thee and make them lavish spenders, Oh God, of enthusiasm, encouragement, cheerfulness and good will.

Make them prodigal in their praise and may they ever turn where true wisdom is found into deliberations which now are before them. And when the last calculation is completed and the task done, may they merit Thy well done; Amen.

President Hutcheson: Thank you, Dr. Hildebrand. We are deeply grateful to you for your appropriate invocation. We will be pleased to have you remain

* Assistant Vice President—Engineering and Maintenance of Way, Seaboard Coast Line Railroad.

with us for so long as you may desire. However, if you feel it necessary to leave at any time, please do so.

I am glad to see so many of you here this morning as we return to our two-and-one-half day convention following an abbreviated one-and-one-half day session held last year. Because the important work of the Association cannot receive proper attention in a one-and-one-half day meeting, it is the present intention of your officers and directors to continue the two-and-one-half day format in future years.

You will be pleased to know that, just a short time before this session started, the registration stood at 1,550 members and guests.

We are especially pleased to have the ladies present and welcome them to attend any and all of our sessions. While I am sure that most of the husbands would prefer that they frequent this place rather than the State Street stores, I am sure that they will enjoy themselves there and at the convention activities which have been planned for them here at the hotel and other places. I particularly invite them to attend the closing business session of our convention which is scheduled to commence shortly after noon on Thursday. The new officers of the Association will be installed here at that session.

I will now introduce those sitting at our speaker's table, your officers and directors, special guests, and many of our past presidents. As I call their name, we will appreciate their standing momentarily to be recognized. Please withhold your applause until all have been introduced.

First, I would like to present our past presidents, who are seated at my right, beginning with our most recent past president, J. M. Trissal, president 1966–1967, vice president—Real Estate and Development, Illinois Central Railroad, Chicago.

A. V. Johnston, president 1965–1966, chief engineer, Canadian National Railways, Montreal, Que., Can.

T. F. Burris, president 1964–1965, retired general manager, construction and maintenance of way, Chesapeake & Ohio Railway–Baltimore & Ohio Railroad, Huntington, W. Va.

L. A. Loggins, president 1963–1964, retired chief engineer, Texas & Louisiana Lines, Southern Pacific Company, Houston, Tex.

R. H. Beeder, president 1961–1962, chief engineer system, Atchison, Topeka & Santa Fe Railway, Chicago.

F. R. Woolford, president, 1959–1960, retired chief engineer, Western Pacific Railroad, San Francisco, Calif.

B. R. Meyers, president 1958–1959, vice president—engineering, Chicago & North Western Railway, Chicago.

Wm. J. Hedley, president 1956–1957, retired assistant vice president, Norfolk & Western Railway, Clayton, Mo.

G. M. O'Rourke, president 1955–1956, retired assistant engineer maintenance of way, Illinois Central Railroad, Chicago.

G. W. Miller, president 1954–1955, assistant chief engineer, Canadian Pacific Railway, Montreal, Que., Can.

The next man served our Association from 1950 to 1964 as secretary and executive secretary, Neal D. Howard, executive secretary emeritus; and beside him is our secretary from 1938 to 1950, Walter S. Lacher, secretary emeritus.

Next, we have our treasurer, A. B. Hillman, Jr., chief engineer of the Belt Railway of Chicago.

I am sure most of you know the next man because of the nature of his position in our Association and wide travels around the country. I am referring, of course, to Earl W. Hodgkins, our executive secretary.

The first two gentlemen to my left are your senior vice president and your junior vice president.First, your senior vice president, H. E. Wilson, assistant chief engineer system, Atchison, Topeka & Santa Fe Railway, Chicago. Your junior vice president is H. M. Williamson, chief engineer system, Southern Pacific Company, San Francisco, Calif.

I will skip the next four gentlemen for the moment.

Next, I want to recognize the members of your Board of Direction in the order of their seniority on the Board.

D. H. Shoemaker, chief engineer, Northern Pacific Railway, St. Paul, Minn.

M. S. Reid, assistant chief engineer—maintenance, Chicago & North Western Railway, Chicago.

J. B. Clark, chief engineer, Louisville & Nashville Railroad, Louisville, Ky.

J. A. Rust, senior assistant chief engineer, Southern Railway System, Atlanta, Ga.

H. W. Kellogg, regional assistant chief engineer, Chesapeake & Ohio Railway—Baltimore & Ohio Railroad, Richmond, Va.

F. H. McGuigan, assistant engineer of structures, Missouri Pacific Railroad, St. Louis, Mo.

E. Q. Johnson, chief engineer, Norfolk & Western Railroad, Roanoke, Va.

R. M. Brown, chief engineer, Union Pacific Railroad, Omaha, Neb.

J. M. Salmon, Jr., chief engineer, Clinchfield Railroad, Erwin, Tenn., and

E. H. Waring, chief engineer, Denver & Rio Grande Western Railroad, Denver, Colo.

Gentlemen, you may now applaud.

(Applause)

President Hutcheson (continuing): The first official item of business on our program is the approval of the minutes of the 1967 Annual Convention, which were published in the June–July 1967 Convention issue of the AREA Bulletin, No. 607, a copy of which was sent to each member. Unless you wish to start a filibuster, or I hear some objection or correction to those minutes, I shall entertain a motion that the minutes be approved as published.

J. J. Dwyer (C&O Ry.–B&O RR.) I so move.

(The motion was duly seconded, put to a vote, and carried.)

Address of President T. B. Hutcheson

President Hutcheson: At this point in the program it is the traditional duty and privilege of your president to highlight the activities and accomplishments of the past year. During the year ending with the 1967 March convention, several important constitutional, procedural and administrative changes were made by the AREA and the AAR Engineering Division. Therefore, one of the principal tasks of your officers, directors and the office of the executive secretary during 1967 has been the implementation and execution of these changes.

One of the most far-reaching changes, particularly as to its affect on the Industry which your Association serves and its place in that Industry, was the adoption of a Plan of Organization and Rules of Order for the Engineering Division, AAR. This action placed the Engineering Division in an organizational status equal with other AAR divisions, and put it in a position to make positive contributions to the

Railroad Industry. Thus, the engineering profession within the Industry now has a proper vehicle for expression and implementation of its views in Industry decision-making. Greatly increased cooperation and collaboration with other AAR divisions and sections has been experienced this year as a result of this change.

I am happy to announce that each AAR Member Road has designated a voting member to represent its interest in the work of the Engineering Division, with the exception of one small railroad. A subcommittee of the Engineering Division's General Committee, composed of D. H. Shoemaker, chief engineer, Northern Pacific Railway, J. B. Clark, chief engineer, Louisville & Nashville Railroad, and M. S. Reid, assistant chief engineer—maintenance, Chicago & North Western Railway, has under consideration how best procedurally to keep chief engineering officers of Member Roads informed on matters before the Division. It expects to make its initial report in the near future.

Within AREA, several constitutional changes have required implementation. One of the most important of these has to do with the geographical distribution of membership on the Board of Direction and of the elected members of the Nominating Committee. The 1968 elections are the first on the new regional basis. But three years will be required to complete the new organization under an orderly plan. After three years the Board will have one director from Canada, four directors from the eastern district, two from the southern district and five from the western district. The president, two vice presidents and two past presidents are members at-large.

Important changes in membership qualifications allow engineers and officers of non-carrier railroad companies to be eligible for the grade of Member, as well as those employed by technical, service, research and development organizations, and scientific societies and associations. This broadened membership policy has been called to the attention of engineers so situated, with a resultant expansion in membership and in service to those segments of the engineering profession. The base for Junior Membership was also broadened to include supply companies and all of the railroads, associations and organizations mentioned above.

During the past year AREA has continued its interest in matters related to the professional standing of engineers in railway practice. For many years it has collaborated with professional organizations in the broad practice of engineering. Our principal efforts during the past year have been with the American Society of Civil Engineers, and with the National Council of Engineering Examiners.

ASCE, through its retiring president, Wm. J. Hedley, also a past president of your Association, approached AREA with the request that a committee representing both organizations be formed to undertake a study of relationships between them, and to investigate areas in which collaboration and cooperation might be desirable. With the approval of your Board and of the Board of ASCE, such a committee was formed. ASCE representatives are Mr. Hedley, assistant vice president, Norfolk & Western Railway, now retired, as chairman; R. H. Beeder, chief engineer system, Santa Fe Railway; and Wm. R. McConochie, vice president, De-Leuw, Cather & Co., Chicago. W. R. Bjorklund, director industrial engineering, Northern Pacific; C. T. Popma, assistant vice president—engineering, Penn-Central; and myself as chairman, represent the AREA. The work of this joint committee is well underway, and it is my belief that this cooperation will result in much benefit to both organizations.

The 1968 ASCE National Meeting on Transportation Engineering was held

February 16 through February 23 in San Diego, Calif. This was the sixth such meeting and the fifth in which AREA has participated as a cooperating organization. H. M. Williamson, vice president, AREA, and Chief Engineer System, Southern Pacific, presided at the AREA portion of the program. Occupying a full day, the program was well attended and received. It is the intention of your officers and directors to continue participation in these important national transportation conferences.

The other area of collaboration mentioned was that with the National Council of Engineering Examiners. During the past year the AREA Board appointed a committee composed of Professor W. W. Hay, of the University of Illinois, a past AREA director, as chairman; H. M. Williamson vice president, AREA, and chief engineer system, Southern Pacific; and W. H. Huffman, past director, AREA and chief engineer of the North Western, to work with this organization, principally in directing attention of the National Council to the implications of the geographically diversified practice of railway engineers, and to keep railway engineers informed as to activities in this field.

Among the procedural and administrative changes within AREA itself during the past year have been improvements in the pamphlet outlining committee assignments for study and research. This pamphlet is the Association's major effort to organize and systematize its committee's activities. It deserves the careful study of each committee member so that his service to the committee may be at its best. In addition to the normal distribution to committee members, beginning in 1967 a desk copy was sent to each chief engineering officer so that he will have immediately before him the assignment of engineers under his charge to the various committees and the scope of the committee subjects under study.

Other administrative changes include streamlining of convention procedures. Among these changes are: Removal of presentation and approval of Manual changes from the convention floor; the elimination of brief status statements and progress reports which do not add to the knowledge of the listeners, advance the state of the art or assist in the discharge of the assignment; and the adoption of a schedule giving committee chairmen definite advance knowledge of years in which they have the option to present a special feature. This year's experience has shown that a more thoughtful and thorough review of Manual changes results from the new procedure. These changes make it possible to enliven the convention and make it a more meaningful forum for the exchange of ideas. This convention's program of outstanding special features reflects the favorable response of committees to this change.

Another important administrative change has been the reorganization of the Convention Arrangements Committee, which is among the most important in the Association. Handling conventions ranging from 1300 to over 2500 delegates is a tremendous task, requiring both knowledgeable and dedicated service. Major objectives were the establishment of needed continuity in management, more efficient handling of conventions, and closer supervision over the hotel staff's adherence to plans and specifications for the convention. Under the new setup the Board has appointed M. B. Miller, division engineer, Penn-Central, as its first manager, with E. G. Gehrke, the Association's assistant secretary, as assistant manager. J. E. Spangler, principal assistant engineer—public crossings, Seaboard Coast Line Railroad, is the current president's representative. Mr. Miller is a long-time member of the Convention Arrangements Committee, and the Association is deeply in his debt for agreeing to undertake this important work.

At its November 17, 1967, meeting the Board of Direction authorized change in status of the Special Committee on Systems Engineering to a standing technical committee, Committee 32—Systems Engineering. This action recognizes the outstanding job the officers and members of the committee have done in laying a firm foundation on which to build future accomplishments, and at the same time the great importance of computor technology and the systems engineering concept on today's railroads. The computor demonstration at this convention is a solid indication of this committee's progress and dynamism.

The work of Committee 13 was reorientated and enlarged. Its name was changed from Water, Oil and Sanitation Services to Environmental Engineering. This committee will work on assignments in the broad areas of water pollution control, air pollution control, land pollution control, industrial hygiene, design, construction and operation of plant utilities, and corrosion control. You will recognize that these areas are becoming increasingly important and are much in the public's attention.

During the year a special subcommittee from Committee 13 and Committee 18 was organized to maintain contact with activities regarding high-voltage ground return, a matter of much concern not only to the Railroad Industry, but also to other public utilities.

At the 1967 Annual Convention, your executive secretary said, in part: "Your officers and directors hope that one of the main accomplishments in the 1967 Association year will be a significant increase in membership, and they earnestly solicit the efforts and assistance of each AREA member in achieving that end." The Board Committee on Membership, under the able direction of J. B. Clark, chief engineer, Louisville & Nashville Railroad, has been active in bringing to the attention of the profession the career and other advantages which result from membership. The efforts of Mr. Clark and his committee have borne good fruit. As of January 31, 1968, the total membership of your Association was 3,423, an increase of 121 over the same period last year, and the highest total in the history of the AREA. In its efforts the Board committee has had the wholehearted support of the membership. Your continued support in this area is needed to overcome attrition and provide future growth.

The plan of holding annual regional meetings, in order to extend the services of the Association and to allow for fuller participation by members, particularly younger members, was continued. The third such meeting was held November 7, 1967, at the Marriot Motor Hotel, Dallas, Tex., to serve the membership in the central southwest section of the United States, and in Mexico.

It has been my privilege to attend each of the annual regional meetings since the inception of the program. Each has surpassed the last not only in attendance but also in service to the railway engineering profession in its locality.

The entire program of the last meeting was interesting, stimulating and thought provoking. One of the highlights was a presentation by G. Rodriquez, Assistant to general manager, tracks & structures, National Railways of Mexico, who spoke on the construction of the Chihauhua–Pacific Railway. The talk and accompanying film acquainted those in attendance with the extremely difficult engineering problems involved in the construction of railways through the most rugged mountain terrain. The films were breathtakingly beautiful, and the engineering solutions to the problems encountered were both interesting and of the first order of professional excellence. It is my hope that this will be a strong beginning of an increased participation by our members to the south in the affairs of the AREA.

Following the collapse of a highway bridge over the Ohio River on December 15, 1967, President Johnson, out of concern for the safety of all bridges subject to public travel, appointed a White House Task Force on Bridge Safety, under the direction of the Secretary of Transportation, Alan S. Boyd.

The Federal Railroad Administrator, A. Scheffer Lang, called upon Thomas M. Goodfellow, president, AAR, for the appointment of a committee from the railroads to be charged with making a comprehensive review of the Industry's current practices relating to the design, construction, inspection, rating and maintenance of railway bridges, and to report its findings to the Task Force. With myself as chairman, members of this committee are:

H. M. Williamson, chief engineer system, Southern Pacific, vice chairman.
J. F. Piper, chief engineer—maintenance, Penn Central.
E. Q. Johnson, chief engineer, Norfolk & Western.
J. W. DeValle, chief engineer—bridges, Southern Railway System.
B. R. Meyers, vice president—engineering, Chicago & North Western.
R. M. Brown, chief engineer, Union Pacific.
W. E. Robey, system bridge engineer, Atchison, Topeka & Santa Fe.
E. T. Franzen, chief engineer, Missouri Pacific.
G. V. Guerin, then chief engineer, Great Northern, now retired.
J. R. Bowman, chief engineer, Terminal Railroad Association of St. Louis.
R. R. Manion, vice president, AAR.
G. M. Magee, assistant vice president—research, AAR.
E. W. Hodgkin, executive vice chairman of the Engineering Division, AAR, and secretary of the committee.

Beginning its work January 19, 1968, the committee, using the recommended practices contained in the AREA Manual related to these areas as a minimum, conducted a comprehensive survey of bridge inspection, rating and maintenance practices on nearly 500 railroads, representing 99 percent of the railroad mileage in the United States.

By February 21, 1967, the committee had sufficient returns in hand to consider an initial report to cover the Nation's Class I railroads. A report, made March 5, 1967, on Class I railroads and covering 94 percent of the Nation's mileage, indicated that bridges on all Class I railroads undergo a major inspection by qualified personnel at least once a year; and, moreover, that at least half of these roads inspect their bridges from two to six times a year. The report reflects that railroads have procedures to maintain bridges to rated capacities, and that the Industry publishes once annually, in one volume, tables stating maximum dimensions and weights of loads which may be handled over the various lines of each railroad.

Returns are yet to be compiled for Class II and switching and terminal roads, comprising 6 percent of the Nation's mileage.

The Bridge Safety Committee is being assisted in its work by the staff of the AREA and the Engineering Division, and by the AAR Research Center.

The AREA and the Engineering Division, AAR, has enjoyed a long and profitable working relationship with the staff of the Research Center, AAR, under the charge of W. M. Keller, vice president—research. Until just recently the Engineeting Research activities were under the direction of G. M. Magee, former director of engineering research. Mr. Magee was recently promoted to assistant vice president—research, with broadened duties and responsibilities. This relationship has continued throughout the past year, and I wish to acknowledge on behalf of AREA and the Engineering Division their debt to this Department for its excellent assistance to our technical committees, and our appreciation for its cooperation.

The financial affairs of the Association will be reported on later in detail by A. B. Hillman, Jr., chief engineer of the Belt Railway of Chicago, and treasurer of your Association. During the current year AREA has had unusually heavy expenditures due to the necessity of reprinting the Manual and Portfolio of Trackwork Plans. This has resulted in a deficit operation. The Association is faced with an immediate 30% increase in its printing costs. These increased printing costs and other necessary increases in costs are a cause for concern to the officers and directors. The Board Committees involved have these matters under study and have taken action to maintain a solid financial position. They have authorized an immediate increase in the prices of all AREA publications to bring them in line with the increased costs. Also, a proposal to increase annual AREA dues by $5, effective January 1, 1969, will be submitted to the membership later this year.

I would like to acknowledge, with grateful appreciation, the extremely able assistance received during the year from the executive secretary and his staff. The Association is indeed fortunate to have the services of Earl Hodgkins in this important post.

I would also like to express my appreciation to the officers and directors of the Railway Engineering—Maintenance Suppliers Association for their assistance and cooperation during the years past and particularly for their support during this convention. The current REMSA exhibit, which opened yesterday in Donovan Hall at the International Amphitheatre, is an outstanding one. Because of the cancellation of the exhibit originally planned for last fall, nearly three years have passed since the last engineering and maintenance of way exhibit. For that reason, and because of the excellence of the exhibit itself, I am sure that each of you want to include a visit to it in your convention schedule.

The program of ladies' activities is an important part of any AREA Convention. I am delighted that a number of our ladies are with us at this session. We are grateful for their contributions to the convention. I would particularly like to express my appreciation to the wives of the officers and directors who have been of great assistance to Mrs. Hutcheson in the organization of the ladies program of this convention. I hope that you all will enjoy your stay here in Chicago. I particularly want to thank my wife, Virginia, for her patience and for the support she has given me during the past year.

In closing, I wish to express my deep appreciation for the recognition and honor which you have bestowed upon me as president of your Association. It has been a privilege to be associated with the officers, directors, committee chairmen and the executive secretary through this 12-month period. Any credit for the year's accomplishments is due in large measure to the efforts of these outstanding men. (Applause)

President Hutcheson (continuing): We will now hear the report of our treasurer, A. B. Hillman, Jr., chief engineer, Belt Railway of Chicago. Mr. Hillman.

Report of the Treasurer

A. B. HILLMAN, JR.: Mr. President, members and guests:

It is with some reluctance that I must say I am not the bearer of glad tidings, as was the case last year. It was anticipated that the year 1967 would be a poor one financially for the Association, with Disbursements exceeding Receipts by $26,110, due primarily to a complete reprinting of the Manual and the Portfolio of Trackwork Plans to replenish depleted stocks of these two Association publications. I am, (however), somewhat relieved to report that the deficit for the year was not $26,110 as anticipated; it was $22,363.34.

I shall not attempt to go into the many individual items of receipts and disbursements, all of which will be individually shown in the Association 1967 Financial Statement, along with the General Balance Sheet and the Treasurer's Report that will appear in the June–July Proceedings issue of our Bulletin, but I will comment briefly on some of them. Total Receipts were $4,124 higher than expected, due to Membership Accounts exceeding estimation by $2,200, Manual $1,200 and Track Plans $800. That Manual receipts exceeded estimation was due to the reprinted Manual becoming available at a date that enabled back orders to be filled late in 1967, with resultant higher than anticipated revenue for the year. All other items of receipts slightly exceeded expectations with the exception of Advertising, which was under expectation by some $1,000.

Digressing a bit, and while perhaps it is not the prerogative of the Treasurer to single out a particular publication of the Association for comment, I feel I would be remiss if I did not report that Manual Receipts for 1967 totalled $10,237.88, which again illustrates the high regard in which this AREA publication is held by the entire engineering profession.

Getting back to my report, on the expenditure side, total disbursements were $101,087.51, an overexpenditure of only $377.51.

The year 1968 will again, as in 1967, present a problem in Association financing, and will result in a serious unfavorable balance of Disbursements exceeding Receipts. This situation is predicated on the extremely high increase (30 percent) in the cost of printing Association publications in 1968, increased postal rates, and a general increase in the cost of doing business. There is little possibility of augmenting Association receipts, except the increasing of the sale price of Association publications to reflect, in part, the rising cost of producing them, and increased membership.

Therefore, it is incumbent on all officers and members of the Association to join in an effort to increase AREA Membership, with resultant higher receipts, and to keep to a minimum the number of members, who, for one cause or another, may relinquish their memberships during the year. And, through the combined efforts of all, to keep to the minimum Association expenditures during the year, especially those of a non-remunerative nature, so that the inevitable loss for the year 1968, with Disbursements exceeding Receipts, may be kept to the lowest amount possible.

To this end I solicit your support.

(Applause)

PRESIDENT HUTCHESON: Thank you, Mr. Hillman. Our entire membership should be concerned with our financial problems and support the Board of Direction in its attempts to solve them. I don't say we don't have similar problems in our personal lives. I would be the last to deny that. We also have them in our national life and in our international life and in every other aspect of our life.

The next order of official business is the report of our executive secretary, Mr. Hodgkins.

Report of Executive Secretary

E. W. Hodgkins: Mr. President, members and guests:

The year 1967 was a great success for the American Railway Engineering Association, from nearly every aspect. The brightest light is the level of AREA membership. Last year, I was fortunate in reporting that the downward trend in membership had been reversed. This year, I am extremely pleased to report that our membership soared to the highest level in the Association's 69-year history.

For the third straight year, the demand for the Association's publications was unbelievably high, particularly for the Manual of Recommended Practice for Railway Engineering and the Portfolio of Trackwork Plans. Furthermore, from the orders received during the last 2½ months, it looks like this demand will continue for the fourth consecutive year.

Other factors involved in the Association's forward progress during 1967 include its third highly successful Regional Meeting and the interest in and activities of its 23 technical committees, both of which remain at record high levels.

However, in spite of all this bullish atmosphere, there is one big black cloud in the bright Association sky. What else but finances—and don't we all have problems in that area of our personal lives today. Now, don't jump to conclusions, the financial position of the Association is sound, but it is in the process of eroding, and if erosion is not halted it can endanger an entire structure. The report of the Treasurer had more to say about this problem, so suffice it for me to say that the Board of Direction already is considering corrective action, and that this action will attack the problem from more than one direction.

Your officers and directors are hard working and dedicated men, who spend many hours each year furthering the interests of the Association and of the industry they serve. Furthermore, they do not hesitate to make revolutionary decisions when investigation and analysis have proven that such is necessary or desirable to keep the Association on a forward, dynamic course. These men deserve the fullest support and admiration of the entire membership.

As President Hutcheson has announced, the dedicated efforts of the officers, directors and members, including the chief engineering and maintenance officers of railroads, has resulted in a level of membership that is the highest in the history of the Association. To those who contributed to this outstanding effort we say, "Well done, thou good and faithful servant." However, in the next breath we must request your continued good offices in not only maintaining this level of membership but pushing it even higher. The average level of attrition each year still approaches 250, even though it fell to what might be a record low level in 1967. Let's twist to our advantage the familiar phrase generated in Vietnam, "search and destroy," to "seek and recruit." There are many railroad officers in many departments and job classifications who would benefit from AREA membership and in turn advance the vital work of AREA by contributing a portion of their time, experience, knowledge and talents to its object, "the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways."

Your efforts are urgently needed—can the Association depend on you for help?

The activity of members in the important work of our technical committees remains at record high levels. In 1967, 1206 members were assigned to 1333 places on the Association's 23 technical committees. This year, 1246 members are assigned to 1350 places. But, there still are vacancies for more than 250 additional members.

The work methods of AREA committees can be invaluable in preparing men for higher positions and more responsibilities. This procedure enables the wide knowledge and experience of all the members of AREA committees, from a large number of railroads, to be applied to the studies of the subcommittees. What an outstanding educational experience AREA committee work can be for our younger members! This is perhaps one of the greatest benefits the individual railroads and the railroad industry as a whole derives from the American Railway Engineering Association—assistance in the technical and administrative preparation of their young engineers and supervisors for greater responsibilities—to the extent these people are allowed to participate in AREA general and committee activities.

A large percentage of AREA committee work is directed toward the preparation of progress or final reports for information; toward revising material appearing in the AREA Manual of Recommended Practice for Railway Engineering, the AAR Electrical Manual of Standards and Recommended Practice, and the AREA Portfolio of Trackwork Plans; toward the development of new Manual and Portfolio material; and toward carrying out special projects related to their assignments.

Speaking of AREA publications, I would like to announce the availability of a new book just off the press. Its title is "Structural Fatigue and Steel Railroad Bridges," by Professors W. H. Munse and J. E. Stallmeyer, of the University of Illinois, and Freeman P. Drew, research engineer of structures, Association of American Railroads. The contents were compiled from the script of a seminar on structural fatigue sponsored by AREA Committee 15—Iron and Steel Structures. Copies of this book are available for inspection and sale in the State Ballroom where registration will be conducted for the next 2½ days. The information contained in this book will be of inestimable value to structural engineers, and several universities have ordered multiple copies for use in graduate courses in structural engineering.

Looking Ahead

Let's look ahead for a moment or two.

At the present time, four future convention dates and locations have been definitely established. They are:

1969—March 10–12, Pick-Congress Hotel, Chicago
1970—March 23–25, Palmer House, Chicago
1971—March 15–18, Sherman House, Chicago
1974—March 19–21, Sherman House, Chicago

Dates satisfactory to AREA in 1972 and 1973 are in the process of being worked out by the executive secretary and the Palmer House sales manager, in line with the policy established two years ago by the Board of Direction that the Palmer House is the official AREA Convention hotel when satisfactory dates are available or can be cleared. Obviously, 1969, 1971 and 1974 depart from that policy. The former was established before the policy was developed; the latter two because satisfactory dates could not be made available by the Palmer House. The dates and location of the 1971 and 1974 Conventions were established to accommodate the

Railway Engineering—Maintenance Suppliers Association because its officers had reserved space in either the International Amphitheatre or the rebuilt McCormick Place for exhibits in those years. This follows the return of REMSA to the 18-month pattern of exhibits, alternating between March and September.

Members can continue to look forward to AREA Regional Meetings, at least as long as they continue to support those held in their general regions, and a few of them are willing to pitch in and help make the plans and arrangements for them. The Regional Meeting held thus far, in the Northwest, Southeast and Central Southwest, have proved to be extremely popular and attendance has been over 200 at each one, and has increased to a small extent each year.

So much for the good things of Association life; now let's take a look at some of the harsher things. As reported, our membership level is the highest in the 69-year history of the AREA, but it will not stay there without continued efforts on the part of the officers, directors and members, and chief engineering and maintenance officers as well. A strong AREA can make even greater contributions to railway engineers and railway engineering and maintenance of way and structures than it has in the past. The muscle and sinew of AREA are its members, but without a large quantity and high quality of members, those willing and able to contribute to the work, the Association will have trouble in accomplishing all the work in front of it.

The AREA is in a particularly strategic and advantageous position to make positive and outstanding contributions to the railroad industry, as well as to the railway and civil engineering professions. The Plan of Organization and Rules of Order adopted early last year for the AAR Engineering Division solidified the relationship by formally coupling the Engineering Division to the governing and technical-committee structure of the AREA. However, to realize the potential of the combine, committees, particularly those working in sensitive and strategic areas, must "retool" to be able to handle quickly, efficiently and fully, the assignments submitted to it by the railroad industry, either directly from railroads, from the AREA Board, from the AAR vice president of operations and maintenance, or from other AAR divisions and sections. In many such cases the traditional AREA procedure for working on assignments is too laborious and requires too much time from request to answer. The times in which we live today simply are moving too fast for us not to have expeditious means of handling problems which the industry submits to us for solutions. On the other hand, if railroad management wants fast and full answers it must realize that the answers can be developed only by those engineers on their staffs qualified by training and experience to take the problem and work out practical solutions. This takes time and frequently a certain amount of travel for the individuals concerned. Committees cannot progress assignments satisfactorily if only half of a 10-or-so-man task force or special subcommittee could not attend a vital meeting, or participate in the correspondence leading up to the meeting. Such problems have been extremely vexing in trying to progress some of the special problems now in the hands of a number of AREA–ED technical committees.

The days, weeks, months and years ahead will not be easy for railway engineers and their Association. But, the challenge of problems and obstacles has always spurred dedicated men to overcome them and emerge triumphant. I assure you there is no doubt in the minds of your officers and directors that many such men hold membership in the Association and are already making outstanding contributions to the work of our committees, and stand ready to make even greater contributions if given the opportunity. Furthermore, you may rest assured that the officers and directors will be in the vanguard of all such work and activities.

The slogan used during the 50th Anniversary Year (1949) of the American Railway Engineering Association has never been more appropriate than it is today . . .

"A Past of Achievement—A Future of Opportunity"

(Applause)

President Hutcheson: Thank you, Mr. Hodgkins. Gentlemen, you have heard the reports of our Treasurer and of our Executive Secretary. A motion is now in order that these reports be accepted.

(A motion to accept the reports was made, duly seconded, put to a vote, and carried.)

President Hutcheson (continuing): I would now like to recognize one of those at our speaker's table who was not introduced earlier in the program. He is H. R. Miller, president of the Railway Engineering—Maintenance Suppliers' Association, and I would like to give him an opportunity to bring greetings from that outstanding group of railroad suppliers, the members of which work so closely with all of us.

Mr. Miller, we are pleased to recognize you and your Association here this morning and will be glad to hear a word from you.

Greetings from REMSA

H. R. Miller: Mr. Hutcheson, members and guests of the American Railway Engineering Association. It is my privilege to appear before you as a representative of the Railway Engineering—Maintenance Suppliers Association. Our members enjoy the close and cordial relationships that exist between our respective associations. It is a real privilege to be affiliated with you and to have a share in your activities for the improvement of our railroad systems.

As you all know, we have at the Amphitheater the largest exposition of railway maintenance equipment ever put on display. Buses between the Palmer House and the Amphitheater leave every 15 minutes starting at 8:00 am and ending at 5:00 pm. On Thursday, the exhibits will close at 4:00 pm.

Our membership wishes to extend to the members of the AREA, your wives, and guests, to join us at the REMSA reception this evening at 6:30 in the ballroom on the fourth floor. We are gratified for your past attendance at this social function. On behalf of the members of REMSA, congratulations and best wishes for the success of your 67th Annual Convention.

(Applause)

President Hutcheson: Thank you, Mr. Miller. We appreciate your kind cooperation. We also appreciate the splendid cooperation from your group, the Railway Engineering—Maintenance Suppliers group and its predecessor groups who have rendered invaluable assistance to our Association and to the railroad industry. We look forward to a continued profitable relationship with your organization.

You may be certain that all of those present will visit the exhibits sponsored by your group. We will be delighted to have you stay for the remainder of the morning session. However, knowing that you have a busy day before you, we will understand it if you feel you must leave.

One of the outstanding features of our opening session is the Keynote Address by an outstanding member of our profession or our industry. There is no doubt in my mind that what the speaker tells us will properly set the stage for the intensive, busy sessions ahead of us today and tomorrow and will stimulate and inspire us as we embark on a new Association year following this convention.

The speaker is well known to most of us and it seems almost superfluous to make any extended introduction. However, for the benefit of the few who have not had the privilege and pleasure of knowing him, I will give a brief sketch of his background.

The speaker was born in Phillipsburg, Kan., and graduated from the University of Illinois with a Bachelor of Science degree in railway civil engineering. He began his railroad career on the Pennsylvania Railroad in 1934 at Philadelphia as an assistant on the engineering corps, advancing to assistant supervisor the following year. He served in that capacity until 1938 when he joined the Great Northern as office assistant to the vice president of operation, subsequently being promoted to trainmaster—division engineer at Klamath Falls, Ore., and terminal trainmaster at Minneapolis, Minn.

From November 1942 to January 1946 he was in military service, serving with the Military Railway Service of the U. S. Army Corps of Engineers. The speaker was released from active army service with the rank of major. Returning to the Great Northern, he was appointed engineer maintenance of way at St. Paul and to chief engineer in 1954.

In 1956, he joined the New York Central as assistant vice president—engineering, subsequently being promoted to assistant vice president—operations, assistant to president and vice president. He was serving in the latter capacity at Washington, D. C., at the time of his appointment as vice president, Operations and Maintenance Department, Association of American Railroads, on September 1, 1964.

During these years our speaker has been an active member of the AREA, having joined it in 1939. He served on Committee 1—Roadway and Ballast, from 1947 until he assumed his present position. He was elected to a three-year term as a director of the Association in 1956.

With this background and as the head of the largest single department in the AAR, in which the AREA functions as the Engineering Division, our speaker is eminently well qualified to talk to us. It gives me great pleasure to introduce our Keynote Speaker, Raymond Rex Manion. Mr. Manion.

Keynote Address

By R. R. MANION

Vice President, Operations and Maintenance Department,
Association of American Railroads

R. R. MANION: Thank you very much, President Hutcheson. When he started my introduction, he said he was going to brief it, and I thought, this is one time I am not going to have to confess being a gypsy all these years. But he fooled me.

First off, I would like to congratulate you, President Hutcheson, your Board and your committees and your hardworking staff on the record of really outstanding accomplishments this past year, and most particularly the very apparent willingness to face change, to alter your organizations to meet the changes taking place in our industry and to move forward.

Your President has honored me again this year by asking me to participate in your annual meeting and address you at your opening session. I am pleased to do this. And I must also say that I am again awed by the job of trying to contribute usefully to your deliberations in the light of all the things you have got going on and the things you are thinking about doing.

For many years I have watched the products of your efforts and observed at least some of the applications of your recommendations in their various forms. The respect your recommendations command is attested to by their substantial adoption not only at home—that is, on your own lines—but broadly across the nation and all around the world.

It is characteristic that engineers are responsible people; it is most apparent that Railway Engineers are. The professional way you go about arriving at your conclusions is the reason for the respect your work has earned. A bit later I wish to pursue this thought somewhat.

My remarks today have been billed on your program as the "Keynote Address." The use of this term and the remarks of your president seems to imply that the "Keynote" speaker will say something that will set the tone for the deliberations and accomplishments of all of you people during the several days of your meeting, or perhaps reflect the tone of your reports and discussions. It's possible, I suppose, that your Keynote speaker could strike the right "bell" and produce the right tone so that the reverberations would be heard and heeded throughout the session and hopefully carry through to your next meeting. Well, that's questionable—in fact, so far as this speaker is concerned (and I lean somewhat on experience), it's most unlikely!

However, don't lose heart or hope—and I won't! But I have another thought in this connection—one, I hope, more practical, more promising of success.

Actually, of course, the *tone* of this meeting, of all of your meetings, is established by the "bells" *you* and *your committees* have rung between times—by the problems you have tackled, your success in solving them and what actions have been generated by you as a result of what you have determined.

When your findings point the way or lead to improved standards or procedures that enable the railroad plant to become ever safer and more efficient, and for railroads to be operated more competitively and progressively, to be able to employ more efficient and productive equipment—you are pulling on the right ropes.

Isn't it important—in fact necessary—though, that you be *heard* in the right places? If your efforts are to be productive of real progress—and progress we must have—the results of these efforts must be translated into action. This is not to suggest that you've not been getting action. But with the fast pace, now growing faster, in our industry in the application of new techniques and technologies, in facing up to heavier and more demanding traffic requirements, it is clear that full coordination of all the involved elements of the business must be secured. Engineering considerations and potentials must be brought to bear along with marketing and operating planning.

While your fine and thorough Bulletins and Manual changes impart valuable information to the members of the AREA and other railroad engineers, are the conclusions and recommendations getting to others who need to know?

I have mentioned the fast pace of the industry in accepting change. This carries with it, of course, the need for continuous review of established procedures and standards and the timely modification of recommended practices. This is not the easiest thing in the world to do. To be on the *action* side instead of the *reaction* side not only necessitates being fully aware of new developments in equipment and operating changes, but actually requires the use of sound indicators of what's coming next. It is most gratifying to me to note that many of your committees have already established special groups and efforts to plan for future developments of their particular responsibilities to provide for our transportation system needs 5, 10, perhaps 15 years ahead. I am happy, also, to see that your Board is moving to establish a group to provide guidance and coordination for this important work.

Last year at this time we were talking about the new structure of the Engineering Division of the AAR which, as you know, is woven into the fabric of the AREA. It is taking awhile for us to learn how best to use this—but here is your tool, at least one of them, for implementation of your decisions and exercise of cooperation and coordination with the other working divisions of your industry. The full interchange of intelligence and joining of forces in forging progress are as necessary on an industry-wide basis as they are within your own individual companies. The avenues available for accomplishing this exist, and are really worth exploring and exploiting. Well, this is a "gong" I've struck before, but I hope it is heard.

And, speaking of hearing—there are others who also ring "bells" and while we're sounding off, we must also listen. As "shapers" of at least part of the direction in which the railroad industry moves, it's necessary that we clearly hear other signals—such as, what does our public want and need? What can our railroads do (as conceived or envisioned by others both in and out of the industry) if we alter the plant? What progress is being accomplished by railroaders in other parts of the world from which we can learn or that should be adapted or adopted by us? Are enough of us listening—or watching—as the case may be?

It won't surprise me very much if we discover shortly—from the next speaker, in fact—that we must be turned in on signals from a new source and that these signals may well have significant bearing on the importance of the work of your committees. While I think you have always had a full appreciation of the importance of the products of your committees—and as I earlier observed, Railway Engineers are real professionals—this was recently demonstrated outstandingly, and your president made note of it.

You doubtless noticed in the latest AREA News (March–April) the article about the Special Committee on Bridge Safety. The results of the survey being conducted by this committee point up in striking fashion the value first of having a Manual of Recommended Engineering Practices for the industry, and next, of these recommendations being so broadly accepted and applied.

To return for just a moment to the matter of being heard, there is one other aspect to this well worth thinking about.

This has to do with the image of the industry before the public. The public should hear our "bells" too. And, I'm speaking about the ones we ring! Not last year's, or the ones of 15 years ago, but the *new* ones. We get a fine assist regularly from the "trade press"—and it is appreciated they are tuned to us. But they may not reach many who should know more about what's going on. Many, whose regular reading is not benefited by such fine magazines, see us only in the light of disappearing passenger service. They need to be made aware that railroads are not only here—they are *up* and *coming*. They are growing to meet the growing transportation needs of the country and are going to keep on being No. 1 in the transportation business. We need to use every opportunity to demonstrate this and every means to put it across to our public.

Ladies and gentlemen, Mr. Hutcheson, thank you for the opportunity to share a few thoughts with you. For many years I have watched the tremendous amount of personal time and effort you devote to this work, and it has been my desire to do anything possible to assist and encourage these efforts. My best wishes to you for continued successes.

(Applause)

President Hutcheson: Thank you, Mr. Manion, for that informative, stimulating and inspiring address. The AREA is proud of its long-standing role in the engineering and maintenance of way functions of the Association of American Railroads. This relationship has existed since 1919, with benefit and credit to both the AREA and the AAR. We thank you for the address and for meeting with us.

We are greatly honored to have with us this morning another AREA member whose name is known throughout the railroad industry and throughout the nation. This gentleman has distinguished himself not only in railway engineering and operation but also in the United States government and in the halls of our institutions of learning. His role in the new Department of Transportation brings him into contact with every facet of the railroad industry.

The speaker was born in St. Paul, Minn. and graduated from the Massachusetts Institute of Technology in 1949 with a Bachelor of Science degree in civil engineering. In 1961 he received a Master of Science degree at MIT, also in civil engineering. He commenced his railroad career in 1949 on the Denver & Rio Grande Western Railroad where he served as roadmaster, division engineer and trainmaster. From 1953 to 1955 he served with the U. S. Army at Fort Eustis, Va., after which he attended the Yale University graduate school for one year.

The speaker joined the faculty of MIT in 1956 as assistant professor of transportation engineering, subsequently serving as a consultant to the U. S. Department of Commerce on the Housing and Home Finance Agency on general transportation policy and urban transportation programs.

He returned to railroad service in 1962 as director of operating data systems for the New York Central. In 1966, he rejoined the U. S. Department of Commerce as Deputy Under Secretary for Transportation Research, subsequently being appointed Federal Railroad Administrator in the Department of Transportation when that department was organized in 1967.

The speaker joined the AREA in 1957 and is a member of Committee 16—Economics of Railway Location and Operation, and Committee 32—Systems Engineering.

Anyone with credentials such as those is eminently well qualified to talk to us on "Railroad Engineering from a New Vantage Point." I am honored and pleased to present our next speaker, A. Scheffer Lang. Mr. Lang.

Railroad Engineering from a New Vantage Point

By A. SCHEFFER LANG

Federal Railroad Administrator, U. S. Department of Transportation

A. Scheffer Lang: Thank you very much, Tom. Well, if you are pleased to have me here, then certainly I am doubly pleased to be here to address this opening session of this year's annual meeting. I am inclined to say this is the nicest combination of business and pleasure I have had for quite some time.

But I found myself, in thinking about what to say this morning, in a situation similar to the one described by Rex Manion; it is a little hard for me to say very much here that is going to add anything to the kind of meeting that I know you are going to have.

It was suggested to me the other day by an associate that speaking before the American Railway Engineering Association would be for me, now with the Government, a little bit like coming home. But I rejected that suggestion because I have never had the feeling that I ever left this particular group. I am aware of the fact that there are many in the railroad industry who feel that someone with a job such as I now have and a title such as I now have, must almost certainly have emerged from some smoke-filled caucus room some place. But I am really quite a disappointment in that regard, because I am just a railroad civil engineer, and many of my longest and most lasting professional associations were made right here in this organization.

But I do recognize that for someone who started out working on a steel gang, I have had some different experience from those most of you have had, and it seemed to me I could draw on those different experiences for the substance of some remarks I hope will be useful. So let me start out with the years I spent on the university faculty. As I think all of you in the room can appreciate, it has become virtually impossible in this country to get a job on a university faculty as a professor of railroad engineering. If one finds himself on a university faculty, as I did, working on civil engineering problems, he will find that he has to develop some other lines of inquiry and expertise if he wants to stay on the payroll. Right now I know of only one fellow who can stay on the payroll as a professor of railroad engineering.

So I had to get into some other aspects of engineering and did so, not reluctantly, and became interested in the technical engineering problems of other modes of transportation as well as railroad transportation, and in fact, ended up spending most of my time working on problems of highway engineering. The work I did in railroad engineering was really the smallest part of my faculty job. One of the important things this did for me was that it gave me an opportunity to look at our problems in railroad engineering from a professional vantage point which was different both in its institutional character and its substance, and the view raised some questions in my mind about the professional vitality and the technical quality of the work we know as railroad engineering. And perhaps more than that, about the institutional setting within which we as railroad engineers operate.

Now many people have suggested that if we have a problem of low professional vitality in the railroad engineering business, it can be traced entirely to the fact that we are not building a lot of new railroads these days, and that therefore we do not have that kind of a stimulus to professional activity. But this is an explanation that I myself reject categorically, because there are more than enough technical challenges for those of us who call ourselves railroad engineers in this day and age to make for a healthy profession as a whole.

I will say that from my vantage point in the university, I could not conclude that those who referred to themselves as railroad engineers were in a professional sense doing a bad job compared to those in other segments of the civil engineering profession. I think, in fact, the railroad engineering profession stands up pretty well in comparison with the civil engineering profession as a whole.

But I did reach some conclusions about our profession, perhaps the most important one of which was that the railroad civil engineer tries to be too darn many things in what is really a very broad technical spectrum. The railroad engineer tries to be a structural engineer and a locating engineer, a hydraulic engineer and an expert on soil mechanics, a metallurgist and even a chemist; and it is really no surprise that someone who tries to be all these things ends up really not being any of them. And it seems to me that this is certainly a major problem we have in what we call the profession of railroad engineering.

Well, after leaving the university and going back in the railroad business, I then somewhat unexpectedly found myself working in government. And my first full-time job in government had transportation research as its focus and included responsibilities in both technical and policy problems of the railroad industry.

So I was forced there not only to think about the technical problems of the railroads, but to put them into context with the technical problems of other modes of transportation. And again this was an interesting experience for me.

I think that the thing which struck me most immediately, as I began to look at railroad technical problems from this point of view, was the very high degree of individual interest which railroad engineers manifest in their technical problems contrasted to what in many areas seems almost to be industry-wide apathy towards the same problems. To put it another way, there were and still are a great many people interested in and capable of solving some of the technical problems that the industry faces. But we always seem to have a lot of trouble mounting an industry-wide or a multi-organizational attack on these technical problems. Those of you who had to suffer through my talk last night at the Western Railway Club will recognize this is a point I was trying to make there in a somewhat larger context.

My most recent experience in government has brought me into contact with the railroad industry on even a broader basis, because now I worry about government policy on such mundane matters as mergers, safety, car shortages, passenger trains disappearing, and you name it. Above all, however, I am concerned with the future of the railroads as part of our national transportation system, because our national transportation system is what the Department of Transportation is all about.

And here again, looking now at the industry from a somewhat broadened point of view, I am continually struck by the extent to which the problems in railroad transportation seem to outrun our collective technical capability to solve them, even though they may not outrun the capability of the individuals who are working in or with the industry.

Well, when I piece these kinds of experience together with my experience working in or with engineering departments on three different railroads (the introduction left out the several months I spent working for what is now my railroad, the Alaska Railroad), I can't help asking questions about whether or not we as railroad engineers really have ourselves organized right. Now this isn't a new question. Much of what you have already heard this morning is proof of that. I know that we have been talking about this question of how we are organized in Committee 16 ever since I became a member of it, and I am sure it was discussed there and elsewhere in the Association long before that. But to me the question of how we as railroad engineers are organized has become an increasingly urgent kind of a question.

I noted with great interest the article by Ed Myers in this month's (March 1968) issue of Modern Railroads, entitled, "Are Track and Roadway Adequate?" In polling engineering officers, he came across some of the same things that have been bothering me for a long time. He speaks for example of the need for increased research in track and roadway. He points out in that connection, however, that there is now at last some government sponsorship of work in these areas. But what he doesn't go on to say, which I can go on to say, is that most of this work being sponsored by government falls pitifully far short of the kind of work that needs to be done on the technical problems we face.

I thought, however, that even more telling than this question of how much research we are doing on our technical problems was the comment passed along in Ed's article about the need for better people. Allow me to quote a railroad engineer whom Ed didn't identify in that article, an article I am sure many of you have already read, "The real crying need of the railroads is for intelligent young men with an up-to-date background in some of the new technology. I feel very much that the rate of increase of technical knowledge has outstripped a good many of the engineers on the railroads and in the railroad supply industry."

Well, as one who has tried both to hire and educate young engineers, I can testify that this man, whoever he is, hit the nail squarely on the head. We are having difficulty keeping up with new technology and hiring those who can, and it seems to me that this is the most serious possible situation that any industry or profession can find itself in.

Let me repeat the problem. We are not attracting enough first-rate people to the problems in railroad engineering or to the railroad engineering profession. If this keeps up, it is possible that what was once the top engineering profession will ultimately become the bottom one.

Now, there are lots of reasons why we have these kinds of problems in our profession and I am not going to bore you with my ideas about them. But I would like to return to this one thought that I advanced a moment ago, namely, that we may still not be organized right in our profession. I suspect we are in some important ways organized wrong within our individual companies. We have almost certainly been organized wrong at an industry level, and perhaps we are organized wrong as a profession.

Earl Hodgkins outlined some of the questions that we face in this regard in his discussion this morning of the Association's role as the Engineering Division of the AAR. I could raise some additional questions, such as, for example, why do we still hire largely civil engineers for our engineering departments when the educational background of an industrial engineer is really more appropriate to the bulk of the work that gets done in railway civil engineering departments? Why do we have so little research going on that we cannot attract and hold the younger, more inquiring minds that are coming out of our engineering schools? And in fact, why do we continue to subsume under the heading of railway engineering, areas of technical expertise that have long since come to be offered more proficiently by other kinds of engineering disciplines and, in fact, other professional associations?

It seems to me that these are the kinds of questions that individually and collectively we have got to do something about. When I have raised these kinds of questions in conversation with my colleagues here in the AREA over the years, I have often come up against a concern on their part that somehow or other these weren't really questions we ought to be discussing. In fact, I have personally been confronted on many occasions with the argument that it wasn't our place to discuss "AAR Policy" or, alternatively, you would never get the AAR or the AREA Board of Direction to change their thinking on such and such a matter. I have never been a member of the Board of Direction of the AREA, but it is pretty clear from Tom Hutcheson's report this morning that that body does not accept that kind of an explanation as justification for the Association as a whole not addressing itself to the sort of questions that I am raising. And I submit that as individual members of the AREA, we should not accept this kind of justification for walking away from the problems either.

It seems to me that as members we are too often inclined to forget that on matters of railroad engineering we are the AAR. There is no AAR Engineering Division, with all due respect to Mr. Manion, without the AREA, which is an association of individual members. And if we as members of the AREA cannot discuss questions of professional concern to us, then I am not sure who can.

Secondly and even more importantly, I find that we are inclined to forget something that Mr. Manion referred to in passing this morning; namely, that as members of the AREA, we are professionals whose obligation goes beyond playing some passive role in the affairs of our clients. We are not supposed to sit around and wait until we are told what to do. We presumably have some responsibility to tell others what can and what needs to be done. So it seems to me that, as an example, if we are not doing enough research on the technical problems that we as railroad engineers have responsibility for, we should not sit around and wait until someone—be it the AAR Board or the AREA Board of Direction or anybody else—says, well, okay boys, I guess maybe next year you can do a little bit more research. If we aren't doing enough research then we ought to kick like hell, and if we don't kick like hell, then it seems to me we are not acting as professionals, and if this is not a group of professionals, then I think somebody better let Earl Hodgkins know, because he thinks he is supposed to be helping to administer an organization of professionals. And I am sure that the Board of Direction thinks they are supposed to be directing the activities of a group of professionals who have voluntarily banded themselves together for the purposes of enhancing their own profession.

By the same token, it seems to me that if we are, as we quite clearly are, having difficulty attracting to our profession the kind and quality of people that we need in order to make this a really vital profession, then it is incumbent on us to find some ways to do something about that and not merely wait until the people vaguely described as "railroad management," whoever they are (forgetting that we must be a very large share of this "railroad management"), decide maybe the time has come to do something about the dismally low qualifications of the people who call themselves professional railroad civil engineers.

Of course, I know it is a lot easier to talk about these kinds of things than it is to do something about them. And as some of you in the room here know, anybody who has as many unsolved problems of his own as I do, probably should not be talking. But because I have seen these kinds of things from both inside the industry and outside it, they have come home to me perhaps a little harder than they have to many of you.

My own thinking about the problems of our profession is naturally influenced very much by what I expect for railroad transportation as a whole. In that regard I am a great optimist. I am, I guess you could say, very bullish about railroads, because I can see, from the work I have been involved in over the years, a kind of transportation capability emerging that, while it may look something like what we have known as railroads, will actually be vastly superior to anything we have today. And I see moreover a steadily increasing disposition on the part of the government to create and maintain an environment within which this capability can grow and flourish. And obviously, again, I speak here as someone who is considerably closer to that problem than most of you.

Now it seems to me that the railroad engineering profession has an essential role to play in this future. We have problems to solve and we have to attract people into our profession. I don't have the answers to these problems, I only ask whether or not we are organized right to do that job. And I would submit that while our Association has obviously made a lot of progress on behalf of its membership, in considering some of the things that this general question of organization raises, we still have a lot to do.

Thank you.

(Applause)

President Hutcheson: Thank you, Mr. Lang. We appreciate your setting aside a portion of your busy day so you could be with us and give us the benefit of your thinking about our profession and our duties.

Thank you.

I shall, from time to time, as their names become available to me, recognize officials of railroad systems from nations other than Canada and the United States who are with us at our convention. We do have some men from India with us today, officials from the Indian Government Railways—Messrs. Sarma, Divghi and Reddy. If these gentlemen will stand, we will appreciate it.

(Applause)

President Hutcheson (continuing): A fitting finale to our Opening Session is an illustrated talk on a flanged-wheel-steel-rail transportation system that was visualized and engineered from scratch within only the last few years, and on which many millions of dollars have been expended on research, into the best, most efficient and practical system to serve the needs of the people in the San Francisco–Oakland area. The facilities are now being constructed on the ground, under the ground, in the air and under a large body of water.

The program states that B. R. Stokes, general manager of the Bay Area Rapid Transit District would tell us of the exciting and far-reaching things taking place in urban transportation in the San Francisco Bay area. Mr. Stokes was unable to be with us this morning because he had to meet with the California legislature at Sacramento this week.

However, so as not to let the AREA down, he requested his assistant to come to Chicago to present his address. It therefore gives me a great deal of pleasure to introduce L. A. Kimball, assistant general manager, Bay Area Rapid Transit District.

Mr. Kimball, we are pleased to have you with us this morning; the microphone is yours.

(Applause)

(Mr. Kimball read the prepared address which was to have been delivered by B. R. Stokes, general manager Bay Area Rapid Transit District. The address was illustrated with slides, none of which is reproduced herein. The paper follows.)

BART: A Progress Report

I have been asked today to describe progress in the San Francisco Bay Area's rapid transit project and the renaissance in rapid transit that is apparent today across the United States from Boston to Baltimore, Seattle to Los Angeles.

But with your forbearance, I should like to trace the evolution of the concept of rapid transit from planner's dream to the steel and concrete sinewed reality taking shape in our Bay Area community. For a pattern much like ours is taking place in more than a half-dozen cities across the country as these communities seek a supplemental mode of travel.

Pared to the very bones, the concept of rapid transit is the speedy movement of people from suburban centers to prime work areas, or core cities, and their equally speedy return. Basic, yes, but a precept one must never lose sight of as these bare bones are fleshed out into a workable transportation system with its accompanying impact upon its service region.

The San Francisco Bay Area, with its peculiar but endearing topographical features, is tailor-made for a rapid transit system. I say this because of two reasons: the temperament of its inhabitants and the narrow, natural defiles and man-made bridges which historically have funneled goods and people in and out of its major cities.

The first notes of alarm that these narrow transportation corridors could not possibly keep pace with the explosion of mobile man—and the automobile, his second-most prized possession—were sounded in 1946. That was a report from a joint Army–Navy review board suggesting that any long-range solution to the Bay Area's transportation problems would be in the use of an underwater transit tube connecting East and West Bays. This tube is the nucleus of our system today.

In the next decade, it became increasingly apparent that the future growth and well-being of our entire region was being threatened by an inexorable increase in auto congestion. Prominent businessmen expressed fears that the gradual choking of our main motor arteries would strangle economic growth.

Cold statistics show that the population of the nine-county Bay Area, now somewhat in excess of 4,000,000 people, can be expected to reach 6,020,000 by 1980, and that by the year 2000, we will have more than 8,300,000 inhabitants.

Hand in hand with the people explosion was the auto explosion, with the latter even gaudier in its spiraling growth statistics.

During the 10 years between 1950 and 1960, the number of automobiles in the five central counties of Alameda, Contra Costa, Marin, San Francisco, and San Mateo increased more than three times as fast as the population in the driving ages, 16 years and over. By 1975, the total population of these counties is expected to be up 58 percent, inter-county commuters up 41 percent, and inter-urban travel by all forms of transportation up 51 percent.

The crux of the Bay Area's congestion problem is the growing use of automobiles and the declining use of public transit, especially during peak travel hours.

The most serious traffic congestion occurs during the peak periods of commuter movements each workday morning and evening. These recurring travel peaks cause severe blockages and delays on principal highways and in the downtown sections of larger cities.

In the five years between 1954 and 1959, the peak period automobile traffic through the six principal traffic gateways between the central cities and suburbs rose 44 percent, while patronage on existing transit facilities declined 15 percent. The losses from delays through traffic congestion already are appreciable. Unless averted, they will become much greater in the future. Last year, for instance, the San Francisco–Oakland Bay Bridge carried nearly 60 million vehicles for the first time in its existence. At the same time this figure was released, toll bridge authority engineers cautioned that at no time could a traveler expect to cross the bridge without some degree of delay.

In this fertile soil of discontent brought about by mounting highway congestion and a vociferous element opposed to any form of freeway construction, the seeds of rapid transit are nurtured.

Rapid transit people are not dedicated to the obliteration of the automobile. Ours is an auto-oriented society and nothing is going to change that. Our purpose is to provide that missing ingredient in a balanced transportation system so vitally necessary to the environmental well-being of our community. In the face of burgeoning population growth we must accommodate this new growth without destroying old values.

And this is what the Bay Area Rapid Transit District is setting out to do. For we feel that the only way we can restore the automobile and bus to their rightful positions is by clearing the streets and highways of congestion—and the way to do this is by providing a rapid transit system which can lure 50 to 60 percent of the automobile commuters out of their cars and into our system.

The decision to build the BART network did not come easily. It was the culmination of exhaustive studies based on the Bay Area's transportation needs, and of all the known and envisioned types of conveyances. Thirdly, it was based on an extensive cost-benefit analysis of the Bay Area situation.

That tiny spark of an idea that came alive in 1946 was fanned into further life in 1951, when the California State Legislature created the San Francisco Bay Area Rapid Transit Commission. It was composed of 26 business and community leaders from the nine-county area surrounding the bay. Early in its life, the commission hired a joint venture of engineers and asked some simple questions:

1. Is an interurban rapid transit system needed for the Bay Area?
2. If so, what areas should rapid transit serve and along what routes should it be constructed?
3. What types of rapid transit facility would best meet the Bay Area's needs?
4. Is the cost justified?

Six years later—six years of detailed examinations of possible routes, cost studies, community impact—the results were compiled in a sizable report and the four questions had been answered.

First, the engineers, planners and other experts became convinced that the prosperity of the entire region would depend upon the preservation and enhancement of its urban centers and subcenters, and that sustaining such centers as concentrations of employment, commerce and culture would depend on the reinvigoration of interurban transit.

Secondly, the report laid out an arterial rapid transit system operating along mainline channels, connecting each of the centers and subcenters at its heart, with stations located to deliver travelers directly to their primary destinations.

Thirdly, after studying all types of conveyances, from ferry boats to monorail, a system of modern electric trains operating on two rails was deemed the most desirable. This was found to be the only mode of transportation that could meet the high operating criteria laid down for the Bay Area system.

And, finally, the commission report summed up on the question of cost related to benefits in this manner: "The essence of the story is that without rapid transit the region will ultimately pay many times its cost in additional hours of travel time, in additional cost of trucking goods over highways congested by automobiles, in diminished revenues from property depreciated by congestion or swallowed by automobile facilities, and in the premium costs of urban freeways and parking garages. We do not doubt that the Bay Area citizens can afford rapid transit; we question seriously whether they can afford *not* to have it."

Following the Commission report, the District was formed, and in 1962 the electorate of the three counties voted to tax themselves to the tune of $792 million in property taxes to construct and operate a 75-mile duo-rail network linking 15 communities with 33 regional rail rapid transit stations.

And since that historic vote, BART has been looked upon as the bellwether project as nearly a dozen transit systems near the construction or advanced planning stages across the United States.

In Washington, D. C. the Metropolitan Area Transit Authority has been given Congressional approval for a modified subway system and public hearings on that city's regional rail rapid transit system will commence early this year. Such hearings will preface a request to Congress for funds to start construction of the downtown Washington subway in the fall of 1968.

The Metropolitan Atlanta Rapid Transit Authority has adopted a $1.5 million work program for 1968, which includes studies in relocation, architecture and engineering design for its system.

A new transportation authority has been created in Southeastern Michigan to prepare a plan for a fast and efficient transit system to service a six-county area.

Baltimore's 20-year program to provide a 75-mile combination of surface, elevated and subway lines has a 1985 target completion date.

The much-heralded Northeast Corridor, a federally financed project to provide high-speed rail travel between Boston and Washington, is moving ever closer to the start of service. Recently two specially designed rail vehicles reached a top speed of 164 mph on a Corridor test run.

In the Philadelphia–Camden area, virtually all contracts have been let for an $80 million, 11-mile rapid transit extension to the existing network operated by the Delaware River Port Authority. The authority also has placed an order for 75 transit vehicles.

In Cleveland, construction is moving ahead on the nation's first rapid transit route for direct service to an airport. The extension, four miles long and costing an estimated $18 million, is expected to be completed late in 1968 or early 1969.

Here in Chicago, work has started on a five-mile rapid transit extension in the Kennedy expressway and a 10-mile extension in the Dan Ryan expressway. Construction of the two extensions will cost about $65 million, and an order for 150 to 160 air-conditioned rapid transit cars will cost an additional $23 million.

In other Chicago activity, preliminary studies are moving ahead on two new downtown subway systems estimated to cost $300 to $400 million.

New York and Boston both are updating and expanding existing subway systems, with Boston planning a median strip route for a six-mile extension of its southwest corridor.

And you are all aware of the Southern California Rapid Transit District and its 62-mile initial system in and around Los Angeles.

We point with some pride to BART's role as the bellwether system, with its successes and its shortcomings receiving world-wide attention by the mass media and the transit industry. BART will play an important role in every system currently in the planning stage, and it is a role we in the Bay Area are happy to accept.

But most encouraging in the nation-wide renaissance in rapid rail transit is the ever-growing feeling that expressways, freeways, turnpikes and toll roads are not the complete answer. The rapid transit mode offers a choice, an element lacking for a half-century from America's movement in and around our urban centers.

The lure of the automobile is great. It is a warm, upholstered, powerful machine and it contains an average of 1.6 persons during peak commute times as its 260-hp engine inches along at an average speed of 13 mph. We hope to restore it to its rightful place by the introduction of a choice, a chance to travel by a different mode during these peak commute times and permit this powerful machine to perform as it was designed.

And we can do this only by offering an attractive enough choice to divert the auto user to our system, particularly during these periods of peak highway usage.

The only system that would meet the high criteria we used as benchmarks from the start was the system we are building today in the Bay Area, a system of lightweight electric trains operating on wide-gage rails. These trains will be automatically controlled from a centralized computer headquarters, and will be capable of speeds up to 80 mph and average operating speeds, including station stops, of 45 to 50 mph.

Our system will operate an exclusive rights-of-way, completely separated from all other traffic, and with controlled time between trains as short as 90 seconds during peak commuting periods.

Our design capacity will allow us to carry 30,000 seated passengers per hour on a single line, compared to 2500 persons per hour on an urban freeway.

To put it a bit more graphically, a commuter today leaves the city of Concord in Contra Costa County and 1 hour and 15 minutes later he arrives in San Francisco. BART trains will make that same trip in 33 minutes, and will deliver the passenger blocks closer to his destination.

Our production vehicles, and we expect to have a fleet of 450 transit cars in operation by 1975, is a wedding of the best design features of the automobile and the life support systems found only in our space programs. The 70-ft-long vehicle will have upholstered seats, carpeted floors, recessed lighting, and wide, glare-free windows. An automatic air-conditioning system will automatically adjust for the 30-deg difference found in Bay Area temperatures as one progresses from San Francisco to the East Bay.

Our automatic train control program—devised to eliminate human error in operating such a high-speed system—will start, accelerate, decelerate and stop our trains according to a pre-programmed schedule.

An automatic fare collection system, which can instantly scan a commuter's ticket and subtract from it the amount of fare necessary for his trip, should immeasurably speed the flow of patrons in and out of our stations. And the stations themselves, designed by some of the Bay Area's leading architectural firms, have been put together with each community in mind so that their environmental "fit" will not be jarring to the people who live around them.

Once in operation, the BART system is expected to have a dramatic effect on travel habits throughout our district. Peak-hour travel times will be slashed by as much as one-half to two-thirds. Virtually overnight, the system will transplant distant areas into vital, highly accessible parts of the metropolis, greatly broadening the area of reasonable commute and enabling people to live and work anywhere they choose within the three BART counties, and beyond.

Let me turn, now, to the realities of rapid transit before turning to the benefits already visible in our district—benefits that have derived from the hardening of a concept into the imminent arrival of a new transportation mode.

Currently within the three counties we have nearly 60 of the 75-mile network under construction or contract, with some 4500 construction workers on the job as 187 contractors push ahead with our building program.

Compressed air tunneling, the first of its kind on the West Coast, proceeds under Mission Street in San Francisco, while other tunnel excavation is in advanced stages in Berkeley and Oakland.

San Francisco's fabled Market Street is in a state of confusion these days, as piledrivers hammer 100-ft-long steel beams into the earth to form wall supports for our stations at Civic Center, Powell and Montgomery Streets. Similar work proceeds beneath curb-to-curb wooden decking in Oakland, with 50-ft-deep excavations carved out beneath two station locations on Broadway.

Just about a year ago today hard-rock miners climaxed 446 working days through difficult ground conditions to hole through our Berkeley Hills Tunnel, 3½-mile transit link between North Oakland and Central Contra Costa County. Today the tunnel is being concrete-lined, and when completed, BART trains will traverse its length in 3½ minutes.

Perhaps the most important element in our network is the Trans-Bay tube, vital link between Oakland and San Francisco. This massive project now extends more than 1½ miles into the Bay from Oakland, with 350-ft-long tube sections lowered into place and locked together every two weeks. These sections are fabricated and launched at a San Francisco shipyard, concrete-lined and towed into place over a shallow trench extending across the floor of the bay. Delicately maneuvered into place, each section is locked to its mate, made watertight, and the process is repeated for 57 sections. In 1970, when trans-bay revenue operations are scheduled to begin, it will be possible to travel between Oakland and San Francisco in 8 minutes.

Some 27 miles of our system are carried on graceful concrete aerial structures, and that portion of our line is in an advanced state of completion.

In Southern Alameda County, 17 miles of aerial lines extend from our Lake Merritt Station site to South Hayward.

In Albany, a full mile of aerial line is complete, and is the site of a linear park made possible through Housing and Urban Development Department funds. This park, which we hope will be but the first of many such landscaping efforts throughout the system, is complete with wide, grassy, play areas, walkways, lighting, bicycle paths, and open access all along its route. We fully expect that it will match the beauty of our landscaping program at the Diablo Test Track, 4½-mile completed segment of line which has performed for the past three years as the site of exhaustive testing in braking, propulsion, sound reduction and speed. It was here, aboard these rolling laboratories, that we arrived at final decisions for incorporation into our production cars.

We at BART are proud of four landmark agreements reached with the California State Division of Highways for the joint use of narrow transportation corridors within our district by two distinctly different travel modes.

One such agreement concerns a 7½-mile stretch of freeway between Orinda and Walnut Creek in Contra Costa County, where BART tracks will occupy and service two transit stations in the median of a widened and relocated freeway.

A second such agreement was reached in Oakland, where again BART will occupy the median of the new Grove Shafter freeway, with transit stations flanked by roadways in two North Oakland locations.

We will also share rights-of-way with the Division of Highways in Southern Alameda County, and along the Southern Freeway from San Francisco to Daly City.

These agreements have meant the savings of millions of dollars to our taxpayers, and has greatly reduced the amount of real property necessary to build two systems on separate rights-of-way.

Nor have we been laggard in the area of system aesthetics. As I mentioned earlier, we have 14 architectural firms at work on the design of our 33 regional stations, and we feel that our decision to avoid the cookie-cutter approach to overall system design has been a happy one.

Our stations range from a colorful combination of concrete and tile in the hills of Orinda to an essentially all-steel structure flanked by freeway lanes, from clear-span stations under Mission Street in San Francisco and Shattuck Avenue in Berkeley to complex, three-level transportation centers beneath Market Street. They range from the warm browns and textured concrete in El Cerrito to the stainless-steel, marble and deep-blue tile of the Broadway stations. They are distinctly individual, and have been warmly received by the communities they will serve.

Our faith in a multifaceted approach to the environmental "fit" of our system was borne out on March 11 of this year when the San Francisco Bay Area Rapid Transit project received a top national award for overall design excellence. The award was presented at the Third International Conference on Urban Transportation in Pittsburgh, and the BART selection was made under the 1968 Design Awards

Program of the United States Department of Housing and Urban Development. The BART project was honored for its "comprehensive excellence of design" for a totally new transportation project.

But stations must be more than mere architectural triumphs. They must be serviced by swift-moving trains and peopled by patrons. Our schedule calls for initial revenue service in portions of our East Bay System in mid-1970, with trans-bay service inaugurated that same year. Final completion of the entire 75-mile network is scheduled for mid-1972.

I say scheduled, since BART's timetable hinges upon the early arrival of additional funding, put at $144 million by the California Legislative Analyst, Alan Post, and concurred in by our own Board of Directors and engineers.

This additional fund requirement is attributable to two prime factors: an inflationary rate exceeding our early estimates, and system improvements not contemplated when the system was put to the voters in 1962. The concept of rapid transit cannot be static; rather, it must keep abreast of new technology as it evolves, and we have kept pace. This has cost money. The people within our district today are fiercely protective of their environment, and their views have been reflected in larger and more comfortable stations, landscaping beyond that originally planned, and addition design studies on station locations. These, too, have cost money.

Today several measures are before the State Legislature to provide us with the necessary monetary relief. Our board is dedicated to full funding of the entire 75-mile network before revenue operations begin. We are confident that legislative support to complete what will be the world's finest rapid transit system will be forthcoming in this legislative session.

For already, some two years before the start of such revenue operation, our cities and Bay Area businessmen are preparing for the start of rapid transit with a confidence in its performance and rapid commencement of service mirrored most strikingly in a developmental explosion unsurpassed in our three counties.

Since passage of our bond issue in 1962, San Francisco has experienced a half-billion-dollar boom in downtown construction. More than a dozen new or refurbished businesses along Market Street are planning private entrances to our stations.

In Oakland, city planners have mapped out a revitalization of the downtown area around our 12th Street Station, with a hotel and convention center planned within walking distance of the station.

The city of El Cerrito has completely revamped its master plan to take advantage of our station locations, and its planners view BART's aerial structures connecting its stations as the spine necessary to knit together major downtown business and high-density living areas.

The city of Richmond considers its BART station the focal point of concentric rings of development, and the city of Fremont, at the end of our Southern Alameda County line, has ambitious plans for a new civic center, complete with college campus, at our station site.

In Contra Costa County, a major developer placed a 1500-home subdivision in the rolling hills of Moraga due to its proximity to two BART stations. His reason was that rapid transit made Contra Costa County much more inviting for such a development rather than San Mateo or Marin Counties.

Even the city of Brentwood, far removed from the end of the BART line in Contra Costa, has woven the location of a future BART station into its master plan.

BART is a catalyst, and has been since its very inception. It already is providing a developmental tool for the orderly growth of suburban centers, and it will preserve and enhance our core cities.

We can no longer storm ahead macadamizing our precious land areas in a single-purpose effort to better provide for traffic movement to keep these core cities and suburban centers alive and vibrant. There must be a choice—a balance—and BART will provide it.

(Applause)

President Hutcheson: Mr. Kimball, we want to thank you for a most interesting progress report on the BART project and on rapid transit throughout the nation. We certainly wish you well in solving the remaining problems and placing the system into operation. We appreciate your efforts on behalf of the Association and we hope that you will attend other sessions of the convention and visit the REMSA exhibit at the Amphitheater.

Gentlemen, this completes what I think has been one of the most outstanding opening sessions in a long list of outstanding AREA convention opening sessions, 67 in number to be exact. In three stimulating addresses we have been knowledgeably exposed to the winds of change which are now playing their inevitable and important part in the nation's transportation facilities.

Before I recess the meeting for lunch, I would like to remind you that the first General Session will convene here in this room promptly at 1:30 this afternoon. The first special feature will tell the story of another flanged-wheel and steel-rail system that has captured the imagination of transportation people throughout the country—the Northeast Corridor project.

The meeting is now recessed until 1:30 this afternoon.

(The meeting recessed at 11:50 o'clock.)

Afternoon Session, March 19, 1968

(The meeting reconvened at 1:30 o'clock with President Hutcheson presiding.)

President Hutcheson: Good afternoon, gentlemen. Will the first general session of our 1968 Convention please come to order.

The first committee reports to come before this Convention are those of Committee 18—Electricity, and Committee 20—Contract Forms. Both committees are occupying the platform at the same time because they are sponsoring a joint special feature, which will be presented immediately after Committee 20 has completed its report. For your recognition, Committee 18 is on my right and Committee 20 is on my left.

The first committee to report is 18—Electricity, the chairman of which is F. T. Snider, electronics engineer, Penn Central Company, Philadelphia, Pa.

The chairman of Committee 20—Contract Forms, is J. T. Evans, assistant manager, special services of the Penn Central Company, Philadelphia.

As usual, for convenience and to save time a microphone has been provided the chairman so he can make such introductions and comments as he desires without coming to the podium.

Before turning the microphone over to Chairman Snider, I want to extend to each of you the privilege of the floor and invite your comments on, or criticism of, any of the report presentations during our Convention—at least within the time which can be devoted to discussions. When you desire to speak, please address the chair, state your name and railroad, or company, clearly for the benefit of our Convention reporter and then proceed with your comments or questions.

Mr. Snider, you may now proceed, and when your committee has finished its report, please turn the microphone directly over to Chairman Evans for the report of his committee. Mr. Snider.

Discussion on Electricity

(For report, see Bulletin 610, p. 229)

Chairman F. T. Snider: Mr. President, members of the Association and guests: Your Committee 18 published reports on three assignments this year, with brief statements on the others. All assignments will be continued.

Assignment 1—Revision of Manual

Chairman Snider: No revision of the Manual is recommended this year. However, I would like to recognize P. O. Lautz, assistant electrical and shop extension engineer, Atchison, Topeka & Santa Fe Railway. Mr. Lautz will you please stand?

Assignment 4–8—Power Supply, Motors and Controls

Chairman Snider: The subcommittee has been reorganized under the leadership of L. A. West, special engineer, Illinois Central Railroad. No report is presented this year. Mr. West will you please stand?

Assignment 5—Illumination

Chairman Snider: A new subcommittee chairman has just been appointed. He is B. Anderhous, communications engineer, Elgin, Joliet & Eastern Railway. Mr. Anderhous, will you please stand.

Assignment 10—Wire, Cable and Insulating Materials

Chairman Snider: Revisions have been made to numerous national standards during the past year to keep them in accord with current practice. A new specification for impregnated paper-insulated cables has been issued.

A tentative specification for high-temperature silicone-rubber-insulated, flexible cable for railroad equipment has been published. This will be offered as Manual material next year.

Specification 589 for Hypalon insulated wire and cable is now available from the secretary's office.

Assignment 11—Electric Heating

Chairman Snider: No report is presented this year. A. B. Costic, chief electrical engineer, Erie Lackawanna Railroad is chairman of this subcommittee, but he was not able to be with us.

Assignment 13—Railway Electrification

Chairman Snider: K. S. Niemond, assistant to the president–research, Long Island Rail Road, is chairman of this subcommittee, and he will present the report.

K. S. Niemond: Mr. President, members and guests: Subcommittee 13 submits a progress report, as information, on the general subject of railway electrification. We are reporting on three assignments. The reports may be found in Bulletin 610, December, 1967, starting on page 232.

The first assignment is 13-A, Develop a Report on Physical and Operating Statistics on Railroad Electrification, Domestic and Foreign. The table published under this assignment, giving data on electrified railroads throughout the world, was originally published in January 1962 and was then prepared by Harry Brown. E. W. Koch, supervisor—electric traction of the Long Island Rail Road has updated the information to approximately July 1966. We will continue this assignment, reporting every third year.

The report on Assignment 13-D, which begins on page 236 of Bulletin 610, covers a wide area of development in the field of rapid transit as well as railroad electrification. Mr. Birch has gathered a mass of interesting and useful information from various sources, both domestic and foreign. On page 240 you will find some foreign railroad electrification details including a number of photographs. These data were supplied by the Engineering in Britain Information Service. One item is of particular interest and I will read it (the third paragraph on page 240):

"Probably the most important single contribution is the reduction of electrical clearances for the overhead wire from original figures, based on U.I.C. specifications, of 11 in normally and 8 in during the passage of a train, to new figures of 8 in and 6 in, respectively. The reduced clearances were proved safe by exhaustive tests in 1962 and are likely to be adopted by the U.I.C. in the future. On the London–Manchester–Liverpool line they saved £1 million by making alterations to bridges unnecessary, and avoided the need for sections supplied at a lower voltage than 25 kv, so that voltage-selection equipment could be omitted from the locomotives."

The section of our report on rapid transit starts on page 244. Many of the modern rapid transit systems have installations similar to the electrified railroads. As a matter of fact, the electrified Long Island Rail Road is getting to look more and more like a rapid transit system. We will have 270 new cars, with delivery to start this fall.

On page 251 C. F. Mulrenan, signal and electrical engineer, Chicago South Shore & South Bend Railroad, reported on a new coating to reduce corrosion of steel catenary structures. The coating is a commercial compound composed of a special blend of asphalts, petroleum resins, plasticizers, asbestos, mica and solvents. The railroad using this system believes it is more economical to apply and will have a greater service life than a conventional paint system.

I wish to thank the members of my subcommittee for the contributions they have made to this report, which, Mr. President, is respectfully submitted as information.

Assignment 15—Relations with Public Utilities

Chairman Snider: E. M. Hastings, Jr., assistant utilities engineer, C&O–B&O, is chairman of Subcommittee 15 and will present the report.

E. M. Hastings, Jr.: Mr. President, members of the AREA: Subcommittee 15 had two assignments. One was to develop specifications for the crossings of railways by utility companies. This has been done. The specifications have been printed and are available through the secretary's office.

The second assignment is a continuing one—a study of high-voltage d-c transmission. If you haven't heard anything about it yet, you will. The first test on the Pacific Northwest—Pacific Southwest intertie will be made early in 1969, and it may cause the railroads trouble in that area.

There is in the process of formation a subcommittee composed of representatives of Committee 18 and Committee 13 which is going to keep in touch with developments concerning this very important subject and will keep you abreast of what is going on.

Chairman Snider: This completes the report of Committee 18.

Discussion on Contract Forms

(For report, see Bulletin 609, pages 179–180)

Chairman J. T. Evans: Mr. President, members of the Association and guests: I should like to introduce the chairman for our current assignments and then go on to our special feature.

Assignment 1—Revision of Manual

Chairman Evans: The chairman of Subcommittee 1 is C. W. Colborg, engineer of contracts and right of way, Denver & Rio Grande Western. Mr. Colborg, will you please stand?

Assignment 2—Form of Agreement for Handling Truck Trailers and Containers at Terminals

Chairman Evans: The chairman of Subcommittee 2 is J. D. Taylor, assistant vice president, Operating Department, Great Northern. Mr. Taylor, will you please stand?

Assignment 3—Bibliography on Subjects Pertaining to Contract Forms

Chairman Evans: The chairman of Subcommittee 3 is N. L. Grider, assistant engineer, Louisville & Nashville, who could not be with us today.

Chairman J. T. Evans (continuing): Our speaker today, J. W. Diffenderfer, assistant vice president of special services of the Pennsylvania New York Central Transportation Company was graduated cum laude from Bucknell University in 1943 with a bachelor of science degree in civil engineering. After receiving his degree, Mr. Diffenderfer served in various locations on the former Pennsylvania Railroad until appointed to his present position on January 1, 1967.

In 1963 and 1964, Mr. Diffenderfer served as chairman of the railroad's committee evaluating the New York–Washington passenger service and the prospects of its upgrading for higher speeds. In 1965, he served as chairman of the committee developing specifications and evaluating proposals for the new high-speed electric cars for this service, leading to the ordering of 50 new cars in May 1966. He represented the railroad in negotiations with the Department of Commerce relative to the High-Speed Demonstration Program, test-track upgrading and testing programs.

In 1963, he represented the Pennsylvania Railroad on the 11-member United States delegation to study Japan's new Tokaido Line, sponsored by the United Nations' Economic Commission on Asia and the Far East and made a subsequent evaluation of this operation in a trip to Japan in March 1967.

He is a member of the Government Operations and Expenditures Committee of the Pennsylvania State Chamber of Commerce, the Technical Advisory Committee of the Pennsylvania Governor's Committee on Transportation, the Transportation Research Institute Advisory Committee, and New Jersey's Commuter Advisory Committee.

Mr. Diffenderfer is a registered professional engineer in the states of Pennsylvania, New Jersey and Oregon, a member of the Pennsylvania Society of Professional Engineers and a member of this Association.

He is very active in church work and serves as general superintendent of the Grace Chapel Bible School in Havertown, Pa., and as a board member of the American Sunday School Union, the Sudan Interior Mission and the Camp Sankanac Foundation.

In his immediate assignment, Mr. Diffenderfer is responsible for studies and programs related to high-speed rail transportation, suburban rail service, planning, and liaison with various governmental agencies and public authorities relative to matters of long-range significance to the railroad.

With this background you can readily see that Jim Diffenderfer is well-qualified to talk to you about "High-Speed Passenger Service in the Northeast Corridor."

I present to you my good friend, Jim Diffenderfer.

(Applause)

High-Speed Passenger Service in the Northeast Corridor

By J. W. DIFFENDERFER
Assistant Vice President, Special Services
Penn Central Company

J. W. Diffenderfer: Thank you, Jack. Mr. President, ladies and gentlemen. I asked Jack to keep that introduction short. I wanted him to keep it short because I was afraid he was going to get into the fact that I am supposedly speaking for or representing the Committee on Contracts and the Committee on Electricity. In getting into that academic record I was afraid he might reveal that I thought that the subject of contracts was the most dry you can find and that talking about electricity was the downfall of any civil engineer I ever knew. Such expertise probably qualifies me to get up here and speak on behalf of contracts and electricity.

I might say, as far as contracts are concerned, we had an interesting time, in negotiating our first operating contract with the government. First, that is, other than the ones we have made with the Bureau of Public Roads, the Army Engineers, etc. We must recognize that many of the railroads, particularly in the West, have had their lines practically rebuilt in connection with various dam projects.

The parties to an agreement have quite a time when it comes to having someone negotiate with you about something you are not quite sure you want and, at the same time, you are not quite sure they want it, either.

You have probably been reading lately about some of the technical difficulties we have been having with some of our new cars. We think they will take a relatively short time to solve, when compared with the amount of time we spent negotiating this contract with the Government. It was quite an adventure for some of us, especially getting into some of the pet clauses which bureaucrats love to put into such government contracts.

However, having now gone through this type of negotiation I am not quite sure that we would do it again, although if this Demonstration Program proves to be a success, it could well be that we would. We were faced with this fact: if we didn't cooperate with government this time, we would as an industry forever have to quit crying about all the help government was giving our competitors: the airlines, the highways and the waterways. Those transport modes have always been most responsive to offers of government help. They seem to have a way of generating it and using it. The railroad industry has always been somewhat reluctant. We believed we had to do something like this to set the pace, and to test government's sincerity in seeking a solution to its transport problems by some use of the railroads.

The "Northeast Corridor" is the name applied to a narrow stretch of "megapolis," as it is called, which stretches some 450 miles from Boston to Washington. Representing less than 1.6 percent of the nation's land area, it houses about 20 percent of the nation's population. Here, we have about 40 million people, comparable to the number of people residing in Japan's Tokaido (East Coast) Corridor between Tokyo and Osaka.

Our "Northeast Corridor" accounts for 50 percent of the nation's financial activity, 36 percent of its wholesale sales and 20 percent of its industrial output.

The corridor, although stretching from Boston to Washington, is composed of two parts, insofar as we are concerned. Having been in New Haven last Tuesday, discussing some of the problems of the New Haven, I would just as soon not refer to those problems that have been saddled on us in recent months, involving that little stretch of line leading east from New York to Boston, I will, instead, confine myself to the piece between New York and Washington. (Fig. 1)

In this 225-mile stretch, we have about 32 million people concentrated in probably the greatest density of development of any corridor area in this country. Of course, the density is nowhere near what it is in Japan, but the density of the North east Corridor is certainly aided by the presence of the large intermediate cities such as Baltimore, Wilmington, Philadelphia, Trenton, Newark, lying between the two great terminals of New York and Washington.

At the north end, there is the new Madison Square Garden—2 Penn Plaza development built over Penn station, New York. Madison Square Garden is already functioning and the 29-story office building at Penn Plaza is already being occupied. This construction was an engineering feat in itself, on which I believe you are to get a report tomorrow at this convention.

At the southern end of the Northeast Corridor is Washington Union Station across from the Nation's Capitol. Each of these cities is in itself a great magnet of attraction.

In between, there is the main line of the Penn Central. It has a mighty good alignment, developed by engineers over the years. It is completely electrified. A four-track system for the most part, it has some stretches of two, three and six tracks.

In recent years, the railroad has been paralleled by such express highways as Interstate 95, built adjacent to it and costing an average of $30 million a mile through much of the urban area. This is typical of the many new limited-access arterial and interstate highways and freeways which have been built throughout this area. In little more than the past decade, we have seen the construction of a $2 billion highway link from Boston to Washington, including the Kennedy Highway (completed just a few years ago), the Delaware Turnpike, the New Jersey Turnpike, and Interstate 95, on up to Massachusetts. Also, in the same time we have

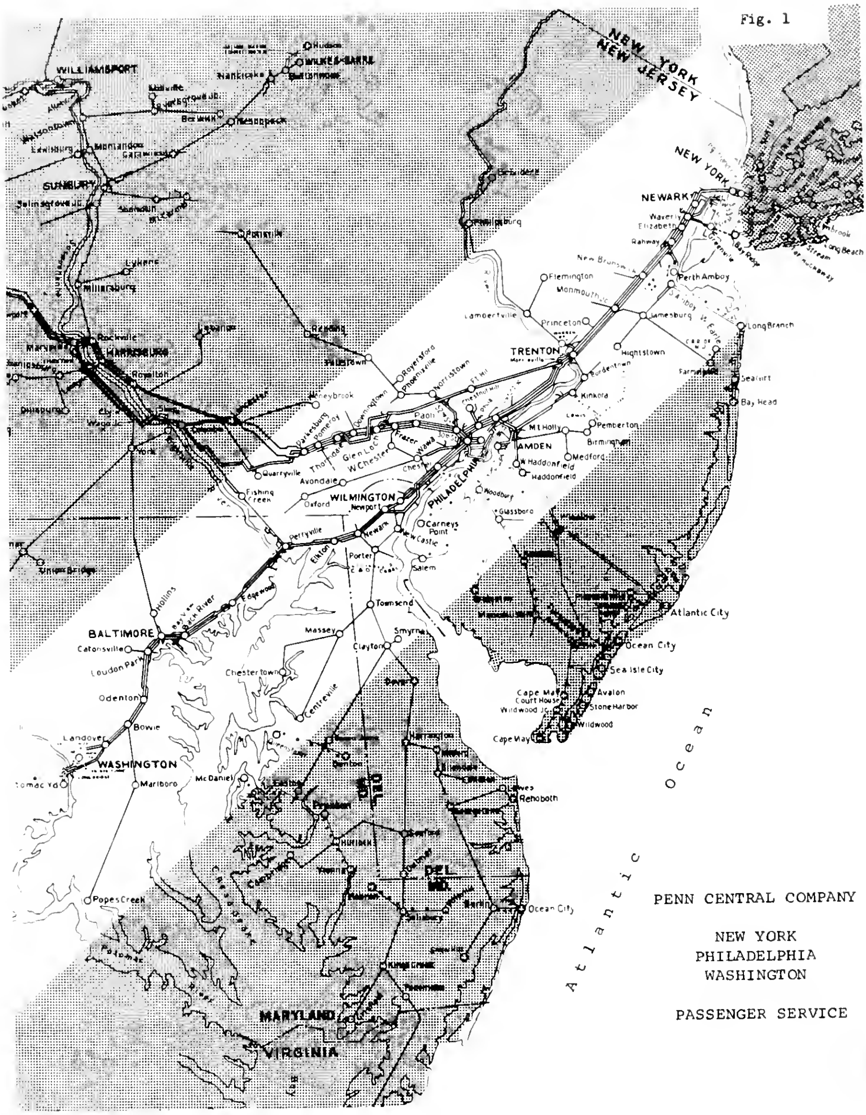


Fig. 1

seen the expansion of airports and the development of an airway system costing another $2 billion in public funds, all of this virtually duplicating our facilities.

I am giving you some of this background, to show the purpose of this demonstration program. It is of importance, not only to the railroad industry, but to the entire public. The public has found with all this new air and highway construction, they got nothing more than increasing congestion, both in the airways as well as on the highways around our metropolitan core areas. This transport strangulation has resulted in the demand for more such facilities, as evidenced by the construction now on the New Jersey Turnpike from Woodbridge northward toward the New York area, expanding it from 6 lanes to 12 lanes. This is simply relocating the congestion to another spot.

Thus, in fighting congestion, especially in peak periods and peak hours of the day, the public decided that it had to find some other solution for the decades to come. It recognized the fact that billions of dollars in public funds will be spent for transportation in the Northeast Corridor in one form or another in the next 10 or 15 years. What kind of transportation was it going to get?

Responsible government officials recognized that for the most part the railroads had an excess capacity, due not only to diversion of traffic to other modes of transportation, but also to improved rail technology over the years. It made sense to evaluate whether in future transport planning, they should make use, not necessarily of a rail system, but of some form of surface transportation to help meet these needs. It is particularly important to provide reliable, all-weather transportation in the Corridor area, since foggy days often shut down the New Jersey Turnpike and the airports for as many as 15 or 18 days in the fall and winter seasons. This slows down the commerce and affects the economic viability of this area. The only fast intercity movement under such conditions is by rail.

With this situation, the Department of Transportation's Office of High Speed Ground Transportation (OHSGT) decided to enter into a demonstration program with us. They found that we had in this area a very good railroad alignment for the most part.

In developing their program, OHSGT chose No. 3 track on our New York Division between Trenton and New Brunswick for an experimental test track. This was upgraded using RE 140-lb welded rail, laid to close tolerances. The sharpest curve is a 0° 37′ curve on which we increased the superelevation to 4 inches. We have been operating test trains at high speeds over this stretch.

Through the interlocking, at Princeton Junction, where we have No. 20 crossovers on the test track, we increased the guardrails from a 9-ft 6-in manganese one-piece guardrail to a 16-ft 6-in hooked flanged guardrail for test purposes. We have also had to be most fussy with the alignment through these crossovers.

We have been able to operate the four-car electric test train of the Department of Transportation at high speeds over this test track. Designed to operate at speeds of 150 mph, it has been running at speeds up to 157 mph. These cars are really rolling laboratories. They have all kinds of equipment, such as closed circuit TV monitoring the action of the pantograph against the catenary wire, to test reactions at various speeds. Instruments record cross-level, profile, gauge and alignment measurements of track conditions. Other data collected includes vertical, lateral, longitudinal, rotational and angular accelerations of the car body; vertical and lateral accelerations of the wheels and wheel bearing housings; sound levels; voltage, current, and phase angle at the pantograph.

We have operated the United Aircraft Turbotrain at speeds slightly above 170 mph throughout this territory.

I might say as a tribute to our men who did the track work, the ride quality has evoked many, many favorable comments. They have done an unusually good job. I think we have proved to a lot of skeptics that conventional rail design, well built, well maintained (and this, incidentally, was done by mass-production methods) can do a good job. This track incidentally went for about one year without being touched, before it was resurfaced with a little detail. All the time, not only with high-speed operation over it, but day in and day out regular, heavy tonnage freight trains were operating at speeds up to 60 mph throughout this territory. So it had a good opportunity for heavy punishment.

Another phase of the program with the government has been the beginning of a marketing project, using conventional equipment. By use of a Kimball type data check, which is used for a hat check or seat check, the origin and destination of every passenger is recorded between the seven major stations. Since June 1966, we have had a tabulation of this passenger information train by train, day by day, summarized by trains and by days. We can take it off by peak periods, or by almost any way we want it, such as by class of passenger, maximum loading figures, or to and from counts. This will be done throughout the demonstration program, so we can evaluate the before and after conditions, and measure the volume changes resulting from the various experiments that take place.

The third major part of our program has been the upgrading and preparation for the demonstration program itself. We began a program of renewing 180 miles of catenary contact wire. The lighter catenary contact wire is being replaced with the heaviest contact wire used in any railroad service in the world. (Fig. 2) It has a section of 346,000 circle mils, 0.68 inch high and 0.482 inch wide. In a figure 8 design, it costs about a dollar a foot at the rolling mill. Only one outfit rolls it, General Cable Corporation. American Anaconda supplies the tin, cadmium and copper alloy. We had to get the help of the Department of Commerce to release some of this copper from the government stockpiles. Ordinarily we renew only 15 miles a year of this wire, but last year alone we renewed 155 miles. We had to make sure we had the heavier wire in place for the high-speed operation. Ordinarily you can figure 40 years of life out of this contact wire. For high-speed operation we didn't want to take any chances, because the heavier wire gives us a much higher current-carrying capacity and reduces the amplitude of the waves set up by the movement and pressure of the pantographs.

Incidentally, compared with the European and Asian catenary systems, which are temperature compensated, we have some problems. This is a rigid system, which sags as much as 8 inches in summer and pulls tight as much as 7 inches high at zero degrees, in winter. Of course, the rigid system works out well in a four, five or six track territory, where there are some real complexities with a temperature-compensated, constant-tensioned system.

With respect to rail, we are laying about 300 miles of track with 140-lb welded rail in lengths of 1,400 and 1,500 ft.

The rail is moved directly from the welding plant near Harrisburg, Pa., on rack cars, especially designed to carry the rail in tiers and facilitate distribution at the rail laying site.

We had over 110 miles of track of welded rail in service when this upgrading program began. The old rail coming out is mostly of 131-, 152- and 155-lb sections.

The new rail is laid in place, using modern machinery in production-line methods. Securely spiked and anchored, it is ready for high-speed operation.

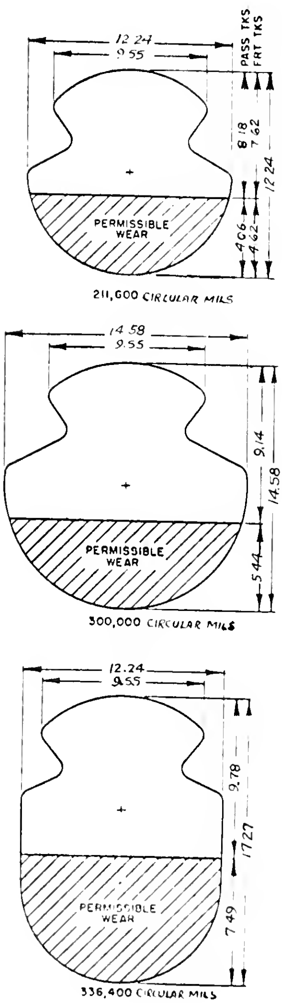
We have completed track upgrading program, retieing (using over one-third of million ties for this project) resurfacing, and reballasting over 350 miles of track.

In some areas, we have upgraded all four tracks. Generally, we have chosen the two inside tracks for the high-speed tracks. You can appreciate the rehabilitation program that was necessary, when you realize that these had previously been

Fig. 2

Catenary Contact wire:

Upper: original wire
Middle: earlier heavy wire
Lower: new, heavier wire



DIMENSIONS IN MILLIMETERS

freight tracks with a speed restriction of 60 mph for passenger trains. Now we are upgrading them for speeds in the range of 110 to 120 mph. Over the test track we are authorized in the time-table for 160 mph for test purposes, although special authorization was granted to make the turbotrain run at 170 mph.

Interlockings have been rebuilt on the entire line. Fortunately, we have a multiplicity of high-speed interlockings throughout the territory, generally every five to six miles. This makes quite a contrast with what the Japanese have. I remember when Rudy Beeder, Gerald Magee, Bill Keller, and a few of us were over there five years ago, we raised the question: "With all the fancy automated signalling and track circuitry that you have, why don't you provide for reverse signaling? They replied that they didn't need it. They said they had too many trains going in the other direction.

"What is going to happen if something breaks down?"

"Well, nothing is going to break down?" They were a little more optimistic than we could be. In fact, for the most part, they have no interlockings except at their stations, which average about 30 miles apart.

Last spring I saw the inevitable happen. One of their trains broke down, due to some roofing blowing onto the track. The railroad was sewed up tight for two or three hours with nothing moving southward. They had no way of moving anything around the disabled train in spite of all the automated equipment they had.

We built these interlocking switches with 140-lb rail over the entire length of the high-speed tracks. In many places where the high-speed tracks were rebuilt, the interlocking switches on other main tracks were rebuilt as well.

Bridges also entered into the upgrading program. Through Chester, Pa., which consists almost completely of viaducts, there were miles of undergrade bridges rebuilt. One main track was placed out of service at a time. All the bridges on that track were rebuilt, putting down new structural members, ties, and grating.

We have problems with some so-called "navigable" streams. We wish the Congress or the Army Engineers weren't quite so generous with their definition of navigability. One mile-long bridge across the Susquehanna River at Perryville, Md., gets a barge about once a year. As a result, we must maintain a swing span with mitre in the rails on the bridge and restrict the speed to 60 mph. We had quite a rebuilding program on this bridge about two years ago at a cost of about $2 million, so it is in real good shape.

There are some other such bridges up in the New York area where we have some navigation problems and where we are trying to work ont some solutions to avoid having to open them quite so often.

Another phase of our upgrading program involved the construction of high-level station platforms. From Philadelphia northward the major stations are equipped with high-level platforms, to speed the time of loading and unloading trains. This can be a very critical factor.

Rather than changing alignments which provide a solution to higher speed operation, we sought some less expensive solution, because the cheapest alignment change we could get would cost us about $8 million for every minute saved. The next cheapest after that was about $10 million. On the other hand, we could pick up two or three minutes with an investment of several hundred thousand dollars in high level platforms. The particular one built between two middle tracks at Wilmington, Del., cost us about a third of a million dollars.

At Baltimore, we took a platform that wasn't being used, but which proved to be the shortest route through the station, upgraded the tracks and built a new high level platform using a precast, prestressed reinforced concrete construction that makes a very beautiful job and goes up rather rapidly.

We used the same type of construction to build a platform at Washington Union Station between tracks 17 and 18.

This platform will have inspection pits underneath. When these trains pull in, the men will be able to work right alongside, inspecting the train while the train is being unloaded and made ready for a return trip.

The platform has a ramp down to the concourse level so it needs no steps or elevators and permits the operation of passenger-operated luggage carts.

At Baltimore, we are installing a powered ramp for an experiment with luggage carts. The luggage carts have proved very successful at Washington Union Station. At Baltimore, however, we have street and concourse level above the tracks, so we are putting in this ramp as an experiment. By handling luggage carts from the platform level directly to the street level, the passengers can conveniently take their own baggage. This job has been completed and is ready for service.

Also, at Washington to help pick up another minute in running time, we installed selective routing through the terminal's three interlockings. A train approaching from New York Avenue at the north end or starting out from the block at Union Station has to operate at a restricted speed from one interlocking to another, because trains are constantly being switched across the main route at each interlocking. However, between the Penn Central's main tracks and station tracks 17 and 18, we will now have selective routing. This enables trains to operate through this area at about twice the speed that they did before. Once a motorman gets his signal at New York Avenue or at the block, he knows he has the route the entire way.

Something else we are trying in connection with this demonstration is the establishment of two park-and-ride stations at the intersection of the railroad main line and major circumferential highways. One is at the Garden State Parkway, about 25 miles from midtown Manhattan. There is to be constructed, a 750-car parking lot, to tap the suburban areas of the Union, Bergen, Essex, Monmouth, Middlesex and Ocean Counties in New Jersey. Today, to get air or rail service to Philadelphia and Washington, they have to fight their way into midtown Manhattan or Newark. They can reach this location in much less time, have a handy parking lot, and use high-speed train service to Philadelphia and Washington, as well as pick up commuter service into New York. This is to be built by the U. S. Department of Transportation and the state of New Jersey. Land here is quite expensive. It costs over a dollar and a half a square foot. That is over $60,000 an acre. It takes about 12 acres to do the job.

At the intersection of the John Hanson Highway and I-495, the Washington Beltway, we have another site.

These roads will provide convenient access for a park-and-ride station there which will tap the two suburban counties in Southern Maryland. Here reside about a million people. This station will save them a trip through the city, either to Washington Union Station or to Washington National Airport.

Today there are between 5,000 and 9,000 people a day flying between New York and Washington. This market, with the automotive and bus markets, are the markets we hope to be able to reach to help meet some of the area's transportation problems. This short-haul air travel takes up the same amount of approach air space as taken by intercontinental and transcontinental flights, and is greatly on the increase. These are experiments we hope to get underway with the beginning of our program.

On the equipment side of the picture, the foundation for the structural components of the equipment really began with the experience we obtained with the "tubular" train which we designed and built in 1956. It happens to be the only one of the postwar lightweight trains that is still in regular intercity operation. I think the rest have been relegated to museum pieces or scrap piles.

The structural design of that train was applied to six experimental suburban multiple-unit electric cars acquired in 1958. These were full of bugs. It is a good thing they were, because from them we gained a lot of experience, which was used to come up with the design of what is today the world's highest performance self-propelled rail car. It is the self-propelled multiple-unit suburban car used in the Philadelphia area. We have 58 of them right now. They accelerate at a rate of 2.2 mph/sec. We limit the top speed to 85 mph, although they do a little better than around 93 or 94 in testing. They are used on runs of 105 miles every day. We used them quite a bit during the New York World Fairs for travel, even from Washington to New York, in multiples of 12, 14 and 15 car trains.

The experience we gained with these cars and the many advantages we had with multiple-unit equipment led us to choose the self-propelled multiple unit car concept for our high-speed equipment. With it, we get uniform axle loading, and much lower total axle loading. We get a uniform performance because we have a much higher thrust-weight ratio regardless of the length of the train, whereas with a locomotive train you have either got too much power or too little power. We also obtain much higher braking performance with dynamic and power braking available on each axle. The multiple-unit electric car also permits us to operate intercity trains with one motorman, permitting a much more efficient operation.

One of the things we wanted to do was try to get a wider car. So, we took several of the suburban cars, equipped them with clearance blocks and feelers, and ran some tests in the tightest place we have in the railroad, our tunnels under the Hudson River at New York. This was done in January, 1966, running at 70 mph. In the tunnels, we have a clearance from bench wall to bench wall of only 11 ft. As the result of these runs, we found it perfectly satisfactory to design a car that had an exterior width of 10 ft 6 inches above the high platform level. This still allowed us enough room, even with tolerable track conditions, to operate through the tunnels at the higher speeds that we do today.

This was resolved into the design of the Metroliner which is 85 ft long and 12 ft-8 in high. (Fig. 3)

There is a cab unit at one end of each car. Some of the operating boys wanted each car to have cabs at both ends while some of us thought they should be run in multiple sets of three or four cars. We could not, however, with our 11-kv, 25-cycle power system, get a transformer small enough to fit under one car but capable of powering two cars.

So ending up with a transformer that was needed under each car, we decided to make each car self-contained, but with a cab in one end. Back to back, you have a complete unit that can run in either direction. We can multiple these up to 20 cars, using a 64-v control circuit.

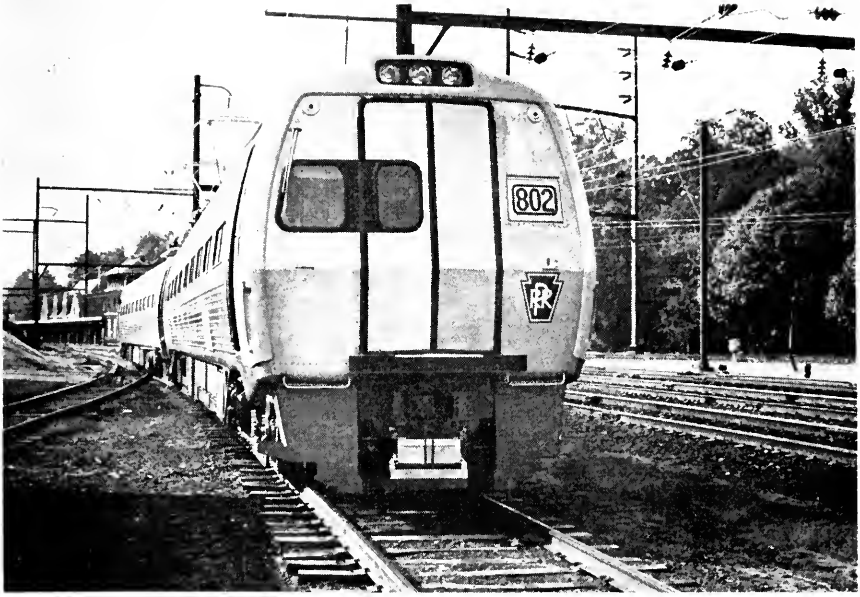


Fig. 3—Stainless steel Metroliners are 85 ft long.

The front end doors enable passengers to pass from car to car throughout the length of the train. They open like a clam shell. A self-supporting retractable diaphragm made of polyurethane comes out. This diaphragm provides an acoustically and thermally insulated passageway.

There are four side doors, one in each end of each side of the car. They are power operated by electric motors, from any door location on the train. The door controls are just inside each door way. The two center buttons control the door at that location; the ones to the left, all the doors on the left side of the train; the ones to the right, all the doors to the right. This not only makes a safer and more efficient operation, but helps speed loading and unloading at stations.

We have a diaphragm also at the non-cab end of the cars to permit passage between cars at that end as well.

Since we don't have to compromise with a hundred different railroads throughout the country and satisfy every one's whim, we were able to come up with our own coupler design; it is the first use of this type of coupler in intercity service. (Fig. 4) It is a hook-type coupler, which enables us to couple instantaneously all of the pneumatic, mechanical and electrical connections. There are 126 spaces for contact buttons in the box below the coupler hook. These carry the circuits for intercom, public address, door and brake indications, and controls for doors, braking, propulsion, etc. The IC pioneered in this in their suburban operations, although not with a coupler this massive. This design will, incidentally, be adapted to all of our new suburban cars in the future. By this we eliminate the need for any man on the

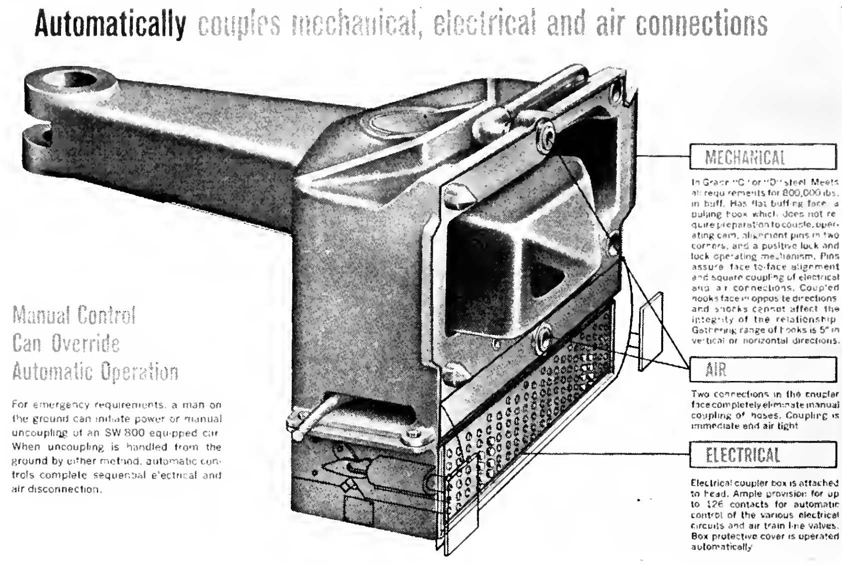


Fig. 4

ground to couple or uncouple, providing greater safety and efficiency. All the coupling is done from the cab. The coupler is self-centering, but can be moved to one side or the other, in case you are in one of those unhappy configurations on a crossover or something like that.

We are also using an automatic air brake test indicator, so that the motorman gets a cab indication every time he makes an application or a release, showing whether all the brakes through the train are applied or released. These devices have eliminated the need for people crawling around on the ground, to make a coupling or an air test. We studied the matter of propulsion power extensively. Each car is powered by four electric motors with a nominal 300 hp rating, but capable of a peak of 640 hp. In other words, with a peak of 2560 hp per car, we really have a baby locomotive under each car.

Power collection from the catenary system is a very interesting problem, particularly at high speed. We have a little different problem from the Japanese whose new Tokaido line pantograph is much smaller than we use here. They had a new car and a new railroad. They had constant wire height of approximately 16 ft 6 inches and a uniform car height of a little over 13 ft.

We have a wire height that is not only not temperature compensated, but varies from 15 ft 3 inches in the New York River tubes to about 22 ft on the main line, and even higher on some side track areas. Thus, we ended up with a very large pantograph.

The Westinghouse-equipped cars are using the German Stemman pantograph. It is a lightweight pantograph. While there were some bugs to begin with, I believe these have been worked out. With the help of high tension buss couplings between the cars, it is hoped that it will behave well in operation at 160 mph. We still have tests to do with these in trains of 6 and 10 car units coupled together.

The French Faiveley pantograph is being used on the General Electric-equipped cars.

The substation view is a reminder that we are also looking into the future with respect to electrification. We have equipped these cars and are equipping all of our future suburban cars to be capable of operation not only on our conventional 11-kv 25-cycle system, but also on 25-kv, 60 cycles. The 25-cycle power give us problems with power supply. By going to the 60-cycle system, we will be able to eliminate the need for transmission systems and will be able to pick up power in a number of different places. Using 25-kv, 60-cycle power, we will be able to reduce the weight of the electrical equipment on our trains and at the same time double the capacity of our overhead catenary system. The key to this is getting the equipment changed over and ready, to have it capable of the voltage and frequency being changed instantaneously. It is an economic matter to change the substations. Physically, you can do that by throwing a switch after the new equipment is in place. But when you have 700 units of equipment in daily use, you can't do that overnight.

Also looking into the future, we have provided the cab signal equipment boxes with space to take care of additional codes. Right now our codes are related to 20, 30, and 45 mph. When the motorman gets a clear indication, his maximum permissible speed is governed by the right-of-way conditions. If we get it into higher speed ranges, such as 150 mph., we cannot risk his trying to remember a myriad of speed restrictions and some code restrictions at various other speeds. This can be done by adding or changing the circuit cards in the box with the control cards and by putting several more code detection units in the right-hand box.

The underside of these cars, incidentally, is just loaded with equipment from end to end. In fact, we have no spare room. We had to put the battery boxes out in front of the trucks. The electrical equipment alone weighs about 25 tons. As a result, each car will weigh in the neighborhood of about 85 tons (loaded).

They are capable of accelerating at a speed of 1.1 mph/second right up to 100 mph, so they can reach 125 mph in a little less than 120 seconds, and reach 150 mph in less than 3 minutes. That is the time it takes a conventional 3-unit diesel train to get to 70 mph with an average-size train.

The interior of the car is what the passenger is interested in. (Figs. 5A and B) By going to a 10 ft 6 inch exterior width, we are able to get interior widths of almost 9 ft 10 inches across the widest part of the curved sides. Floors and sidewalls are carpeted up to the wainscoating. There is carpeting in the ceiling. We have about 3 times as much insulation in these cars. It is so quiet in riding; it may be a little too quiet. We may have to pump some noise in so you don't overhear each other's conversation!

Insofar as windows are concerned, we do not have all the pretty scenery throughout the Northeast corridor area that a lot of people enjoy in the West. This is a businessman's railroad. For the most part, these businessmen are busy reading the Wall Street Journal, doing some work or sleeping. Generally, we don't have the need for the great big windows you encounter a lot of places. We found that most of the time people have the window curtains pulled half way down anyway. So we came up with a new window configuration. The windows are about 16 inches high and about 30 inches long. This design gives us a much stronger car

Fig. 5A—Metroliner interiors are luxuriously upholstered and carpeted.

structure, reduces heat and air conditioning and reduces the target at which juvenile delinquents can throw stones. Now, if some wise guy breaks the glass we don't have as large a piece to renew. We renewed 1400 window panes in our commuter service last year alone.

We have a coach seat which is almost equivalent to a first class airline seat. We are putting 76 of these in each of the coaches; 60 in each of the snack cars.

The snack cars can be identified by their somewhat different exterior appearance. (Fig. 6) They do not have windows throughout the entire length of the car. Instead, there are no windows at the center car location of the snack bar.

The 20 snack cars will have a new food service dispensed across a counter, to meet the food service needs of our coach passengers. (Fig. 7) They will feature such things as an automatic coffee maker, which will turn out a cup of coffee every 10 seconds.

The Metro club cars will have 34 individual, rotating seats, to provide V.I.P.-type luxury. (Fig. 8) There will be electronic food galleys, to provide a tray-type meal service at the seat. This is planned to be included in the ticket price at one stage of the experiment. It certainly should be a big attraction to many of our airline passengers, because this Metro club service will be at approximately the price of an ordinary coach airline ticket.

Each of the snack bar coaches and the Metro club cars has a phone booth. (Fig. 9) It happens to be the most expensive rolling phone booth in the world. The

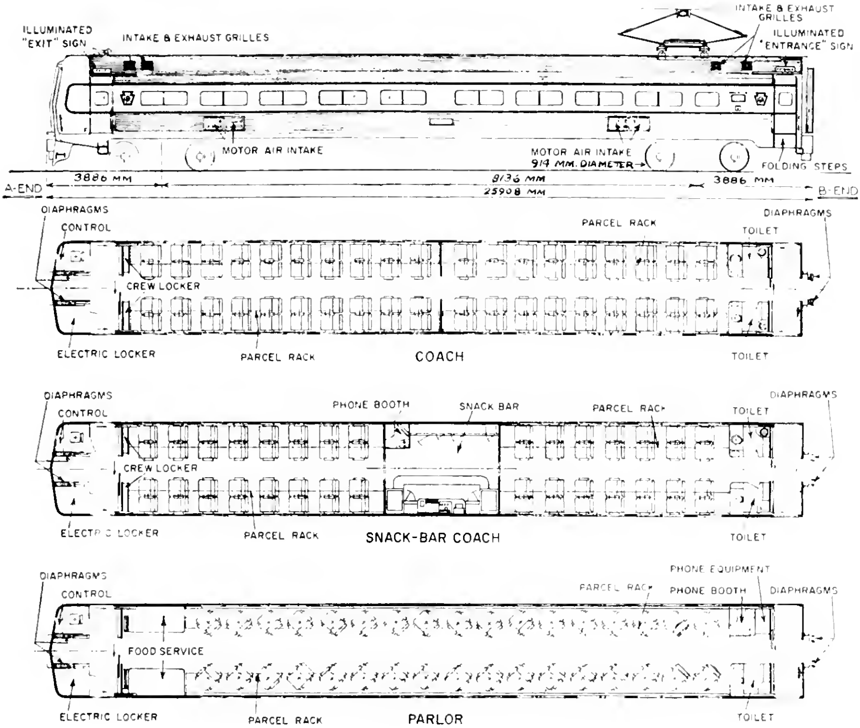


Fig. 5B

Fig. 6—Metroliner snack coach and Metroclub car.

Fig. 7—Each snack coach has a modern food-service counter at center of car.

Fig. 8—Metroclub cars have individual rotating seats.

Fig. 9—Each snack coach and Metroclub car has a phone booth.

AT&T people spent half a million dollars developing and installing this and 8 relay stations along the route. You will be able to talk enroute, through the tunnels. A call will be placed by direct-distance dialing. You will pick up the phone, get a dial tone and with touch tone dial be able to call any place in the country.

We will also be able to receive incoming calls. If your girl friend or secretary wants to reach you all she has to do is call the operator and they will connect her. You will be paged over the public address system and be able to take the phone call from any phone booth on the train.

We are still running freight trains in this area and must never forget that freight is the mainstay of our business. This helps to make an interesting problem of dispatching, as well as maintenance. In fact, the freight train operation is more complex than ever, especially with some of the high-speed piggyback and perishable and special container trains. To make room for the high-speed trains, many of these have to be moved to the outside tracks and mixed up with the local trains. To aid in handling these traffic diversions, we have electrified some additional tracks, put in some new interlocked switches, installed additional reverse signalling and upgraded tracks in addition to the two inside high speed tracks.

We have a grade-separated route with no grade crossings from New York to Newport, Del. This is 125 miles. There are still 100 miles with 20 public grade crossings left on the southern end of the route. We have a campaign underway to get rid of these by closing or by grade separation. Four are in Delaware; 16, in Maryland. The problem in Maryland is that every little jurisdiction, county or township, seems to have power over the crossing. We cannot deal with the public utility commissioner or state highway department in such cases to get a regional and, hopefully, less biased, approach to the problem.

At Harmony Road near Newark, Del., 50 school buses a day go over the crossing and much heavy highway traffic and rail traffic. I happened to catch a picture when the gates were going down, with two or three cars on the crossing, after one train had just passed and another was approaching. They keep deferring their grade separation program, apparently because of pressures for road construction in other parts of the state, even though the Bureau of Public Roads permits them to apply up to 10% of their total Federal allocation toward rail–highway grade crossing separation projects.

We have a setup in the state of New Jersey where they pay 95 to 100 percent of the cost. We have a program where we are still running electrified passenger service between Philadelphia and Harrisburg. It proposes to eliminate the 7 remaining crossings there, at state expense. This will clean up all the grade crossings on that 105-mile route.

There is one we have a lot of fun with in the state of Delaware where they even closed the road four or five months, to replace a one-lane bridge on the other side. There is only one house on this road, right on the other side of the bridge, with a major highway beyond it. Yet, they have been reluctant to close the crossing. We are still hopeful of being able to get this crossing closed out without having to make a grade separation at this crossing.

At Aberdeen, Md., we have a major crossing with the only crossing watchman and manual gates on the entire New York–Washington route. The town commissioners have been somewhat reluctant to close this crossing. It takes a long time to get some of these people to move in spite of new developments, new bridges, and the increasing hazards of highway traffic over a railroad grade crossing.

We even went into customer "brainstorming," to find out what name we should give these trains. We came up with a new name. This is not railroad conceived, nor designed, but it is most appropriate for the area to be served by the new trains.

I might say that the maintenance of way boys did a terrific job of getting the railroad ready. There are some bugs as far as equipment goes. There are some production bugs in the equipment, nothing basically inherent, but there will be some delays that you will read about. As a former maintenance of way man, and still a member of this Association, I am quite proud of the fine job our fellows have done on the fixed facilities and that they are ready from the maintenance of way standpoint for the trains to start rolling.

We are a little modest about it. The government people are going around saying this is the finest piece of railroad anywhere in the world. I would rather confine it to this country, but you fellows may have some different ideas about this, as well!

Nevertheless, we look forward to being able to operate the new Metroliners, I tell most of my audiences that we hope to have this running sometime in the next year but make no promises. We want to make sure that we can have a most reliable operation. We usually tell folks, we hope that when we do start running that we will have them aboard. However, I am afraid there are too many deadheads in this crowd, to invite all you men over to ride. But, since you are fellow maintenance of way men and part of this group, I certainly hope you will get over there to see it. I hope you will patiently wait until we get it into operation and then enjoy the service we will be providing. We will certainly welcome your criticisms.

Thanks a lot for this opportunity to tell you of this project.

(Applause)

President Hutcheson: Mr. Diffenderfer, we thank you for a very fine progress report on the Penn Central's operations in the Northeast Corridor. The result of this undertaking could well revolutionize passenger service. Again we thank you for your efforts on behalf of the Association.

Mr. Evans and Mr. Snider, thank you for your fine reports on the activities of your committees.

Mr. Snider, your committee deals with a most important aspect of railroading, and we look to your committee for guidance in that highly specialized field.

Mr. Evans, we appreciate the efforts of yourself and the members of Committee 20 and know that you are working in a difficult area.

Your committees are now excused with the thanks of the Association.

Discussion on Systems Engineering

(For report, see Bulletin 610, pages 297–308)

President Hutcheson: The next report will be given by the Association's newest technical committee, Committee 32—Systems Engineering. The chairman of this committee is L. P. Diamond, transportation systems planner, Chesapeake & Ohio Railway–Baltimore & Ohio Railroad, Baltimore, Md. Mr. Diamond, will you and your committee please come to the platform to deliver the first report of your committee.

In the interest of time, I request the chairman, vice chairman, secretary and all reporting subcommittee chairmen to take places as close to the podium as possible—the remaining members of the committee will find places at each end of the speaker's table, or in the overflow chairs immediately in front of the platform. This will reduce the time required for those subcommittee chairmen making reports to come to the podium.

Please don't forget that anyone may have the privilege of the floor upon request, at least within the time allowance.

Mr. Diamond, the microphone is yours.

Chairman L. P. Diamond: Mr. President, members of the Association and guests: This is the first report by your Committee on Systems Engineering before an AREA Convention. We were organized as a special committee in the class of 1966 and attained permanent committee status in November 1967. This is a rapid development consistent with the current rapid growth of scientific procedures associated with planning to meet the challenge of industrial change.

We plan to serve the AREA by (a) recognizing and clarifying railway engineering needs, (b) coordinating the specifications and design of all elements contributing to make a working system satisfying the need, and (c) arranging the implementation by others of these system plans. We hope to provide favorable economics in these systems by judicious use of automation, particularly of appropriate computer systems.

During 1967 we worked on six assignments related to efficient computer usage and the engineering of systems. The reports prepared for these assignments and presented in Bulletin 610, December 1967, are progress reports due to the short time since initiation of these assignments.

Assignment 1—Define and Illustrate Systems Engineering Concepts, Developing a Manual of Specifications for Their Application to Railway Engineering

Chairman Diamond: Assignment 1 is designed to produce Manual material. Some large industrial and governmental organizations have given systems engineering an important place and function in their structure. They have their definitions of its nature. We are developing our own definitions and specifications of systems engineering so that it meets the needs of the railroads. This work is under the able guidance of A. W. Polich, chief engineer, Toledo, Peoria & Western, who will give a brief summary of this work.

A. W. Polich: To explain Systems Engineering we must recognize that in our society of expanding technology, it has become increasingly important to reduce the time lag between the appearance of needs and the creation of systems to satisfy these needs. It is important to create a model, or methodology, which technically oriented people can utilize to solve complex systems-type problems. A problem-solving technique which has been successful in the past may not yield acceptable results when applied to more complex problems. The most basic problem-solving technique known to be effective has been called "the scientific method" and it forms the basis for the systems approach.

The systems engineering approach to problem solving, then, consists of five functions:

1. *Definition of the Problem*

Problem definition must be concerned with environment, the current state of technology, organizational policies of the railroad, economic conditions, human factors, what form of input data is available and what form of output is desired, acceptable degree of risk, and others.

2. *Selection of Objectives*

Objectives are the criteria or yardsticks against which the alternatives are evaluated.

3. *Synthesis of Systems*

All known alternatives, including the present system, if one exists, should be listed regardless of how impractical some may appear.

4. *Systems Analysis and Selection of the Best Alternative*

This function provides for obtaining the best solution by comparing the various alternatives to the objectives utilizing the various decision-making tools.

5. *Communication*

Feedback loops are important to be sure the proper interdepartmental information flows are achieved. Feedback, after implementation of the system, is important to provide for continuously evaluating the system, both against the original objectives and any changes in objectives.

Assignment 2—Document Present Computer Assignments of All AREA Committees—Indicating Their Relationships in Overall Systems—with Identification of Potential for Expansion

Chairman Diamond: The purpose of Assignment 2 is to uncover and document the inter-relationships of present computer assignments throughout AREA. Progress has been made in documenting the work of four AREA committees in this regard. H. R. Williams, valuation engineer, Union Pacific, who is providing leadership in this work, will present a brief summary of the progress made.

H. R. Williams: Systems Engineering Assignment 2 is for the most part concerned with a primary objective, that of coordinating computer system activities of all AREA Committees. This will be accomplished through collaboration, joint meetings and documentation of work accomplished. We will also attempt to keep all AREA standing committees and the AREA membership informed as to plans, accomplishments and relationships of the AREA computer research and development work underway.

In 1967 we worked with the members of four AREA standing committees. Resumes of their progress in specific computer assignments are contained in the AREA December Bulletin, No. 610. The Committees involved are: Committee 11—Engineering and Valuation Records, Committee 16—Economics of Railway Location and Operation, Committee 28—Clearances, and Committee 30—Impact and Bridge Stresses.

Committee 32 stands ready to assist all AREA committees as they progress assignments relating to the use of electronic computers. When these assignments are up for discussion on your meeting agendas, we urge you keep us advised. We would like to have a Committee 32 member attend all such meetings. Also, we hope to obtain copies of your minutes of such meetings.

The fantastic speed with which computer science has developed points to the need of continuing education in computer hardware, programming and machine language. Working with your committee conversion problems, we hope to become conversant in computer technology applicable, to better serve the railroad industry and AREA.

Assignment 3—Develop Specifications for Engineering Administrative Systems, Such as PERT, CPM Time and Cost

Chairman Diamond: Administrative systems are important to engineers as they are to all elements of an organization. Assignment 3 is concerned with developing specifications as well as comprehensive applications of network systems of activities, such as PERT. We are not prepared now to offer a report on this important subject, which is under the direction of G. L. Nichols, engineer, methods and procedures, Louisville & Nashville. Mr. Nichols, will you please stand to be recognized.

Assignment 4—Define and Specify All Elements in the Engineer–Computer Interaction, Promoting Simplified and Expeditious Computer Usage by the Engineer in All His Functions

Chairman Diamond: Perhaps the most perplexing relationship in automation is that between man and machine. In the engineer's use of the computer, the interface between man and computer requires clarification. This work is under the able leadership of R. G. Wilhelm, manager systems development, Penn Central. Dick, will you please give a brief summary of your work during the past year?

R. G. Wilhelm: An engineering department of a large company establishing a computer facility faces several challenges, such as scheduling of company computers and available manpower. The department then has to evaluate and choose among several alternates. Factors for consideration are:

1. *Costs*—The system has to be economically justifiable regarding quantity and quality of work.
2. *Manpower*—Different systems would impose different requirements on engineering personnel.
3. *Computer Growth*—The system must possess a potential for the gaining of experience and knowledge about computers in general. It must help teach the engineer that it can solve his problems efficiently and educate him to this as soon as possible.
4. *Software*—Personnel must become familiar and trained in the use of the FORTRAN language and new problem-oriented language (POL), such as COGO and STRESS.
5. *Physical Accessibility*—Engineers should be able to interact with the computer whether running problems or analyzing results.
6. *Potential for Expansion*—The system must possess the capability for expansion within the initial system or to another system.
7. *Hardware Considerations*—The systems to be considered are:
   (a) Company computer facilities
   (b) Small scientific computer system for department
   (c) Service bureau operation
   (d) Time-sharing or computer utility
8. *Time*—Time itself is still another consideration, such as, delivery delays for hardware; delays getting the system working; the initial step of developing programs; and finally delays in using the system or considering turn around time.

The next step is to consider the hardware systems mentioned in Item 7 above in terms of the other factors. One of the problems in considering company facilities is that machine time is not always available on an "as needed" basis. Also, like any service bureau operation, it offers little man-machine interaction.

Time-sharing seems to possess the best method for implementing an initial computer system within an engineering department. However, constant re-evaluation must be continued as development occurs. A small computer with a time-sharing capability to a larger system may be the ultimate answer.

Education of personnel must remain an important matter once the system is installed. There are three main areas to be considered for training of personnel: (1) computer manufacturer, (2) other outside sources, and (3) intra-company training. Certainly, one or all of these sources should be explored where growth in technology is demanded.

Assignment 5—Promote Computer Usage by Railway Engineers Through Demonstrations, Seminars, and Programs of Instruction by Leaders in the Field

Chairman Diamond: One of the most important aspects of our work is the promotion of computer usage among engineers for their own work. It is a strange paradox that the engineer—so prominent in the design of working computers—should find among his colleagues those who are reluctant to use the computer. Our efforts to dispel this reluctance are guided by J. F. Davison, assistant to chief engineer, Canadian National. Mr. Davison is with us today. John, please stand and be recognized. Thank you, John. The report submitted by his subcommittee contains two excellent papers: one by a Department of Transportation contractor, P. W. Lindgren of Melpar, Inc., on Project HISTEP, the high speed Northeast Corridor train, and the other by R. G. Welhelm on QUIKTRAN, a symbolic computer programming language. Included in Bulletin 610 is another paper consistent with the objectives of Assignment 5, by R. A. Stane of our Committee 32, on the use of computers to solve problems in railroad engineering. It is another part of our continuing efforts in this field.

Still another paper on time-sharing, by Prof. A. D. M. Lewis of Purdue, was published in advance of this meeting. It describes the background of the computer demonstrations being made here today and each day of this Convention. Prof. Lewis, you have done an excellent job in organizing these computer time-sharing demonstrations. Will you please comment on them now.

Computer Time-Sharing Demonstrations

Professor A. D. M. Lewis: As engineers we find frequently that we must perform numerical calculations. Digital computers can do in a few seconds computations that would require many tedious and laborious hours of manual effort. Why are we still spending many hours each week in manual computations? More than likely the organization which employs us has a suitable computer. Why aren't we using it? Very likely we aren't using it because we can obtain an answer by hand in a shorter total elapsed time. A common situation is that our work must be sent to another floor in the same building, sent across town to another building, or even mailed to another city in order to have it done by a computer. The delays in getting our work to the computer and having it returned may be anywhere from an hour to several days. There are jobs for which we cannot produce acceptable results by manual procedures in the times just mentioned for obtaining computer results. These jobs we do send to the computer. There are probably many more which could be solved by the computer in a few seconds or a minute or two. We are doing these by hand because of the obstacles which limit our access to a computer.

Computer time-sharing makes economically feasible essentially instantaneous access to a computer for each person that can use one advantageously. With computer time-sharing each engineer, in effect, can be provided with a computer at his desk. This computer is available for his use whenever he encounters a problem in which he can be assisted by a digital computer. The rapid production of results makes it possible for the engineer to explore thoroughly a number of alternate solutions to his problem. The results of one set of calculations may be used in deciding on the next step to be taken.

This year Committee 32, in carrying out its assignment to promote the usage of computers by railway engineers, is conducting demonstrations of computer time-sharing. Terminals for time-sharing systems have been supplied by Com-Share, General Electric, and IBM. These are located in the south end of the Exhibition Hall, which is a short flight down from this floor at the opposite end of the hall.

Demonstrations are being conducted each morning of the convention from 8:30 to 8:55 using a modified version of the AAR car rating program. There will be representatives at the terminals throughout each day until 5:00 pm to answer your questions, to conduct individual demonstrations, and to help you in case you would like to try your hand at the keyboard. We invite you to attend the demonstrations at 8:30 on Wednesday or Thursday morning and to drop by the exhibit during the day.

Chairman Diamond: Keeping contact with the AAR Data Systems Division is an important function of our committee. This liaison is in the field of engineering applications. We are fortunate that this assignment is in the capable hands of Dr. H. N. Laden, director of research services,* C&O–B&O. He could not be with us today. He will speak on Clearances tomorrow morning.

We have been authorized to begin work this year on an important project—designing a system of clearances for loads and cars of excess weight and dimensions. Each member of Committee 32 will be engaged in this work.

I would like to thank all the members, subcommittee chairmen, the secretary, and vice chairman of Committee 32, whose diligent work enabled presentation of this report.

Mr. President, this concludes Committee 32's report.

President Hutcheson: Mr. Diamond, that was an excellent report. You and your committee are to be commended on the outstanding progress the committee has made in such a short time.

We all look to you for knowledge and guidance in this new and increasingly important segment of our work. The computer demonstrations being held on this floor of the hotel have been mentioned several times at the convention, and I add my own urging that you take advantage of the outstanding contributions which Committee 32 is making to our convention by providing that demonstration.

Your committee is now excused with the thanks of the Association you have served so well.

Discussion on Environmental Engineering

(For report, see Bulletin 609, pages 181–192)

President Hutcheson: Gentlemen, we will move along. The next report will also be given by what we might classify as a new committee, not in number or personnel but in name and orientation. At its August meeting, the Board approved the committee's recommendation that it be allowed to restructure and reorient itself, and, as an outward indication of the change, assume a new name. Prior to the change, the committee was known as Water, Oil and Sanitation Services; now it is Environmental Engineering.

The chairman of Committee 13 is J. J. Dwyer, chemical engineer, Mechanical Department, Chesapeake & Ohio Railway–Baltimore & Ohio Railroad, Huntington, W. Va. Mr. Dwyer will comment briefly on his reports and will then give us a glimpse of the future as far as his committee is concerned.

Mr. Dwyer, you may proceed as soon as your committee is in place.

* Dr. Laden was promoted to assistant vice president—research on April 1, 1968.

Chairman J. J. Dwyer: Mr. President, members and guests of AREA. As you have observed by the signs, Committee 13 appears before you today under a new banner, "Environmental Engineering." We shall tell you more about this a little later, but presently our business is the presentation of our annual report for 1967–68.

As President Hutcheson has indicated to you, we are going to make this presentation as brief as possible.

The report of this committee appears in detail in AREA Bulletin 609, dated November 1967, on pages 181 through 192, and covers nine assignments, of which six are presented as completed reports. In view of the completeness of the Bulletin presentation we do not feel that the information needs to be repeated here, and we wish to take time only to introduce the subcommittee chairmen and give them credit for making possible the completed project.

Assignment 1—Revision of Manual

Chairman Dwyer: The first gentleman I wish to introduce is C. F. Muelder, assistant to engineer of buildings, Burlington Lines, chairman of Subcommittee 1. I don't believe Charlie is with us. He had hoped to be, but he is a hardworking man and something probably held him up. A year ago Mr. Muelder presented extensive revisions of Chapter 13 of the Manual and the only changes this year are editorial changes in connection with the change of the name of the committee. Mr. Muelder is also vice chairman of Committee 13 and has contributed much to the reorganization of the committee.

Assignment 2—Corrosion Control—Engine Cooling Systems

Chairman Dwyer: P. M. Miller, mechanical engineer, Grand Trunk Western, is chairman of Subcommittee 2, but he could not be here either. His report is presented as information.

Assignment 3—Design, Construction and Operation of Railroad Sanitary and Servicing Facilities, and Relations with Governmental Authorities Pertaining to These Facilities

Chairman Dwyer: Events in this area were of insufficient importance to warrant a formal report this year. The subcommittee chairman is J. C. Roberts, Fire and Sanitary engineer, Union Pacific. Mr. Roberts, will you please stand up?

Assignment 4—Air Pollution Abatement

Chairman Dwyer: R. N. Johnson, engineer of tests, Elgin, Joliet & Eastern is chairman of Subcommittee 4. Mr. Johnson, will you please stand up? His report is presented as information.

Assignment 5—Small Sewage Disposal Systems

Chairman Dwyer: T. L. Hendrix, senior sanitary engineer, C&O–B&O, is chairman of Subcommittee 5. Mr. Hendrix, will you please stand up? The report is presented as information.

Assignment 6—Railway Waste Disposal

Chairman Dwyer: J. L. Goss is chairman of Subcommittee 6. Mr. Goss, will you stand up? The report is presented as information.

Assignment 7—Cleaning, Sterilizing and Handling Drinking Water Containers

Chairman Dwyer: C. E. DeGeer, assistant engineer water service and fuel facilities, Great Northern, is chairman of Subcommittee 7. Mr. DeGeer, will you stand up. The report is presented as information.

Assignment 9—Protective Coatings for Buried Pipe

Chairman Dwyer: J. W. Zwick, water and fuel engineer, Southern Pacific, is chairman of Subcommittee 9. Mr. Zwick lives in California and it was impossible for him to be here.

Chairman Dwyer (continuing): These gentlemen are the subcommittee chairmen who made possible the Committee 13 report as presented in Bulletin 609.

(Applause)

In our remaining time I should like to take a few minutes to tell you something about the new Committee 13—Environmental Engineering.

You have already heard from President Hutcheson this morning something about our new committee and you have heard from A. Scheffer Lang about the problems we are being faced with. As I listened to Mr. Lang I felt he certainly had us in mind.

Our Secretary of the Interior, Stewart L. Udall, reminds us that man can live about six weeks without food, about six days without water, and only about six minutes without air. And he follows this with the news that we are now using up these precious gifts of pure land, water, and air, by our wanton pollution, our indiscriminate disposal of wastes, at a rate faster than they can be purified and the environment restored by nature. If we are to survive, this trend must be reversed, and without delay. Railroads, like any other industry, are contributing a share of the total pollution load being imposed on the land, water and air. Railroads must now, like any other industry, contribute their share of effort toward control and abatement of the present pollution trend.

As of a few months ago, there was, as far as we know, no body of railroad men actively studying this important matter of the effects of railroad operations upon the environment of man. The American Railway Engineering Association, which has a close working relationship with the Engineering Division of the Association of American Railroads, has taken a giant step toward filling this need by reorganizing and reorienting one of its technical committees to specialize in the environmental area. And thus was born, as of last August 4, your present Committee 13—Environmental Engineering.

The committee will specialize in the environmental areas of land, water, and air pollution control, and industrial hygiene engineering. This will involve designing plant utilities for minimum contamination of the environment, and designing waste treatment plants that will render our discharges harmless to the receiving medium, be it land, water, or air.

In the new Committee 13 organization setup there are seven standing subcommittees covering general categories of information, as follows:

Subcommittee 1—Revision of Manual. The chairman of this subcommittee is C. F. Muelder of the Burlington, who, as I mentioned before, is also vice chairman of Committee 13.

Subcommittee 2—Water Pollution Control. This is under the leadership of J. L. Goss of the Northern Pacific, assisted by A. F. Butcosk of the Southern.

Subcommittee 3—Air Pollution Control, C. E. Peterson of the Milwaukee Road, chairman.

Subcommittee 4—Land Pollution Control. J. C. Roberts of the Union Pacific, chairman.

Subcommittee 5—Industrial Hygiene Engineering. R. S. Bryan, Jr., of the Norfolk and Western, chairman.

Subcommittee 6—Plant Utilities—Design, Construction and Operation, under the chairmanship of T. L. Hendrix of the C&O—B&O, assisted by C. E. DeGeer of the Great Northern.

Subcommittee 7—Corrosion Control, is headed by J. W. Zwick of the Southern Pacific, assisted by P. M. Miller of the Grand Trunk Western.

These major subjects cover the areas to be studied by the committee. Each year, particular topics under these general headings will be selected for research and solution of the problems involved. For the ensuing year the particular subjects are as follows:

Under Water Pollution Control (2), there are three subjects:
(a) Types and Design of Equipment.
(b) Sampling, Instrumentation and Testing.
(c) A Directory of Federal and State Regulatory Agencies.

Under Air Pollution Control (3), the assignment is:
(a) Preparation of Preliminary Code Standards.

Under Land Pollution Control (4), the assignment is:
(a) Solid Wastes Disposal.

Under Industrial Hygiene Engineering (5), the assignment is:
(a) Evaluation of Toilet Types for Locomotives and Cabooses.

Under Plant Utilities Design (6), we have two assignments:
(a) Design of High-Speed Fueling Facilities.
(b) Fueling Station Filtration.

Under Corrosion Control (7), there are also two assignments:
(a) Re-use of Treated Engine Cooling Water.
(b) Engine Cooling System Treatment.

There, gentlemen, is an outline of the program facing the committee. We have all seen how our streams, air and land are being polluted. But the population could do little about it until it got its management—the government—interested. Then real progress began to take shape. By the same token, your committee is well aware of many of the problems facing us on the railroads, in pollution control and related areas, but as previously mentioned, how much we can accomplish is dependent upon the backing we will receive from our managements. We therefore extend an invitation to chief engineers and vice presidents in charge of engineering and maintenance to appoint, as their representatives, one or two key professional personnel on their railroads now engaged primarily in the environmental field, to become active in Committee 13 and its work. To be valuable to the committee, these employees would need to be motivated. We can think of no better motivation than to make their active participation in the committee, attendance at its meetings, and preparation of its reports a part of their company job responsibilities. This type of management support will result in pooling of brainpower and benefits to all roads that none could obtain by going it alone.

Mr. President and gentlemen, I thank you.

President Hutcheson: Mr. Dwyer, your committee is to be commended for its self-analysis and positive efforts to increase its contributions to the Association and the railroad industry. Certainly, you are working in one of the most vital areas connected with our society and with life itself, and no one can dispute that it is one of the most highly publicized areas. The Board will be most interested in the progress you and the members of Committee 13 make, particularly in the next year or two.

Thank you for your most interesting remarks and the efforts of yourself and the members of your committee on behalf of the Association. You are now excused.

(Applause)

Discussion on Highways

(For report, see Bulletin 609, pages 169–177)

President Hutcheson: Will Committee 9—Highways, come to the platform?

The chairman of this important committee is Raymond Dejaiffe, chief engineer, Toledo Terminal Railroad, Toledo, Ohio.

Mr. Dejaiffe, I am pleased to turn the meeting over to you.

Chairman Raymond Dejaiffe: Mr. President, members of the Association, and guests:

The annual report of Committee 9—Highways, is published in Bulletin 609, pages 169 to 177, incl. There have been no recent developments on most of these assignments since the reports were published.

Assignment 1—Revision of Manual

Chairman Dejaiffe: The committee recommended certain revisions to Chapter 9 of the Manual which were published on pages 369 and 370 of the Supplement to Bulletin 610. The subcommittee chairman for Assignment 1, Revision of Manual, is M. A. Wohlschlaeger, engineer of grade separations, Missouri Pacific Railroad. Will he rise and be recognized.

Assignment 2—Merits and Economics of Prefabricated Types of Highway–Railway Grade Crossings

Chairman Dejaiffe: The committee makes no report on Assignment 2 this year, but hopes to be able to report on a new type of steel panel crossing next year. The subcommittee chairman is W. A. Buckmaster, assistant division engineer, Baltimore & Ohio Chicago Terminal. Will he rise and be recognized.

Assignment 3—Merits of Various Types of Highway–Railway Grade Crossing Protection

Chairman Dejaiffe: Our report gives brief statements on four research reports, and our special feature will cover the subject more comprehensively. The subcommittee chairman is R. W. Mauer, special engineer, Atchison Topeka & Santa Fe, and the vice chairman is H. L. Michael, professor and associate director, Joint Highway Research Project, Purdue University. Will they rise and be recognized.

Assignment 4—Investigate Present Requirements and Practices of Marking and Signing Private Grade Crossings

Chairman Dejaiffe: The report on this assignment gives the details of a public utilities commission examiner's report and a new law passed by the State Legislature of California. The subcommittee chairman is H. W. Walbright, division engineer, Norfolk & Western.

Assignment 5—Extent of Use and Effectiveness of Highway-Type Stop Signs at Highway–Railway Crossings

Chairman Dejaiffe: The committee reports on driver observance of stop signs at Oconomowoc, Wis. The subcommittee chairman is K. E. Wyckoff, assistant chief engineer—staff, Great Northern. Will he rise.

Assignment 6—Air Rights for Highways Over Railroad Property

This is a new subject and the committee is developing information for a report next year. The subcommittee chairman is T. P. Cunningham, project planning and control engineer, Penn Central.

Assignment 7—Conduct Study with the View Toward Developing Alternate Types of Automatic Crossing Protection

Chairman Dejaiffe: The committee reports on four special crossbuck signs with blinking lights installed in Missouri on a trial basis. The subcommittee chairman is C. I. Hartsell, assistant contract engineer, Chesapeake & Ohio—Baltimore & Ohio. Will he rise.

The vice chairman of Committee 9 is R. E. Skinner, assistant to chief engineer, Illinois Central, who is not present today. The secretary is C. A. Christensen, engineer of public works, Chicago, Burlington & Quincy. Will he rise.

Chairman Dejaiffe (continuing): We now come to our special feature. Our speaker today is Professor Harold L. Michael, associate director, Joint Highway Research Project, professor of highway engineering, and head of transportation and urban engineering at Purdue University. One would think that would be enough to keep him occupied full time; however, he is also chairman, Department of Traffic and Operations, Highway Research Board; and member, National Committee on Uniform Traffic Control Devices, and many other organizations too numerous to mention. He received his bachelor's and master's degrees in Civil Engineering from Purdue University. He has been a member of AREA since 1954 and a very active and valuable member of AREA Committee 9, for ten years. With all his connections, he keeps the committee informed of future trends and reports before they are made public or published. He is very well qualified to talk on his subject, which is "Factors Influencing Safety at Highway-Railway Grade Crossings—a Summary of Recent Research." Professor Michael.

Factors Influencing Safety at Highway–Railway Grade Crossings—A Summary of Recent Research

By PROFESSOR H. L. MICHAEL
Associate Director, Joint Highway Research Project, and Professor of Highway Engineering, Purdue University

Professor Harold L. Michael: Thank you, Mr. Dejaiffe. Mr. President, ladies and gentlemen: It is indeed a pleasure for me to be here to talk to you this afternoon about this important topic. Most people, I suppose, would classify me as a highway engineer, even though I profess to be a transportation engineer and this is what we try to teach at Purdue University in our transportation engineering program.

Even though most of my experience has been in highways, and we obviously do a great deal of work in that area, I approach you, if you classify me as a highway man, with respect, just as a vehicle ought to approach a railroad. Therein lies the problem, however; vehicles do not, and this is what I would like to talk about this afternoon.

It is not unusual that considerable activity continues in the area of safety at highway-railway grade crossings. With the desirable emphasis in recent years on knowledge and action which would reduce the large number of highway accidents and their resulting property damage, injuries and deaths, has come increased research on the highway-railway accident problem. And more will continue to be done. For example, one program begun in late 1967 by the Department of Transportation was a directive that each state highway department select one grade crossing for each 4000 miles of its Federal-Aid highway system for testing of the most suitable known or proposed system of protection.

Before installation of the most suitable known or proposed system can be done, however, one must have knowledge of the findings available from previous research in this field. A summary of some such findings is the purpose of this paper.

The most comprehensive and perhaps significant of recent research studies in highway-railway grade crossing safety was the one recently completed by Alan M. Voorhees and Associates, Inc. This research was performed under contract for the National Cooperative Highway Research Program. This Program is administered by the Highway Research Board, National Academy of Sciences, Washington, D. C., with funds made available by the various state highway departments through the American Association of State Highway Officials in cooperation with the Bureau of Public Roads. Information for the study was obtained from many sources, including 16 state highway departments, five cities, five counties, the Interstate Commerce Commission and the Pennsylvania Railroad. The report became available for purchase in early 1968. The findings of that research project supplemented, where appropriate, by findings of other research studies will be the basis of this paper.

Of great importance in decisions regarding the improvement of safety at any location is the cost. It is extremely important that funds for safety be spent wisely —at locations where they will be of most benefit. An understanding of the relative importance of the highway-railway grade crossing accident is therefore of real concern. The highway-railway accident accounts for less than 0.1 percent of all motor vehicle accidents each year. On the over 7500 crossings for which data were studied by Voorhees, the average accident rate was less than one accident per crossing every ten years. This low incidence of accidents at crossings means that a sound program to improve safety cannot be based on accident records alone.

The railroad-highway accident, however, has a very high rate of persons killed and injured per accident. Each year about 2.5 percent of all motor vehicle deaths occur at railroad crossings. Anything that can be done, therefore, to decrease accidents at railroad crossings, as rare as they are, will also reduce the number of fatalities, certainly a desirable goal.

Traffic accidents at railroad crossings number about 10,000 each year and result in approximately 1300 deaths and 11,300 injuries. About 3200 of these accidents involve a train and result in 1200 deaths and 3400 injuries. Of the other 6800 accidents at grade crossings not involving a train, about one-half occurred without even a train present. About one-half of the no-train-involved accidents are rear-end collisions involving two or more vehicles. Although only one-third of the total accidents at railroad-highway grade crossings involve a train and the two-thirds that do not also need to be minimized, it is the one-third that do involve a train which result in over 90 percent of the deaths.

What are the characteristics of the drivers who are involved in these accidents? Several recent studies note that drivers involved in railroad-highway accidents have few if any characteristics which differ from those of the typical driver. There is some indication that older drivers may be involved in such accidents at a higher rate than they are in other accidents. It is clear that in a very high percentage of the accidents, the drivers involved did not become aware that a train was approaching the crossing until it was too late to stop.

In about two-thirds of the accidents involving trains, the train hits the vehicle. In the other third, the train is hit by the vehicle. But in the latter cases, about 90 percent of the vehicles hit the train engine or the head end of the train while only in about 2 percent of the accidents is the rear half of the train hit. This indicates that very few drivers hit a train which is in the crossing when they are still far enough away to stop. It emphasizes that the driver did not *see the approaching train in time to come to a stop.* Or in other words to minimize train-vehicle accidents, the advance warning given to the motorist of the approach of a train or of the possibility that a train may be approaching must be improved.

Another of the findings is that the rate of vehicle-train accidents is about twice as high in the winter months as it is in the summer. Further study of these data indicated that the presence of ice and snow or the number of hours of darkness were not the contributing causes. On the other hand, relative humidity was suggested as a possible factor of importance, due to the resulting window fogging and its restrictive effect on the driver seeing an approaching train. Some of the research also indicates that the rate of vehicle accidents increases when the highways are wet, a condition which increases the distance needed to stop and thereby the distance from the crossing in which he must see the approaching train.

Train-vehicle accidents also were found to occur at a higher rate during night-time hours than during day-time hours. Approximately 42 percent of accidents involving a train occur at night while only about 25 percent of the highway traffic is at night, and rail traffic is relatively constant throughout a 24-hour period. Again, however, darkness alone appears to not be the major factor. A peak accident rate occurs between 2 and 4 am in the morning, a rate six to eight times as high as during the day time while for the hours of darkness between 6 pm and midnight the rate is only twice as high as the daytime rate. The important factor may be driver fatigue, or one research suggests, it may be decreased visibility resulting from the frosting and misting of windshields which accompany high relative humidities, which also peak from 2 to 4 am.

Perhaps one of the most important findings of the recent studies and noted by several of them is that the major safety problem is that the drivers involved are not becoming aware of approaching trains until after they have passed their final opportunity to safely stop.

A study of field conditions at railroad crossings found that a driver travelling at the normal highway speed—as most drivers were found to be doing at railroad crossings—often cannot see an approching train in time to come to a safe stop. Improvement of this situation is dependent on two important factors: (1) educating the driver to the fact that at railroad crossings he *must look* for approaching trains and (2) providing a clear area which permits him to see approaching trains when he does look.

In addition to the factor of visibility as an important factor influencing safety at highway-railway crossings, others were also found to influence safety. As in past research the most important factors influencing safety at a crossing were found to be the volume of vehicle traffic on the highway and the volume of traffic on the railroad. The higher the volume on each, the greater the probability of a vehicle and a train meeting at the crossing at the same time and the higher the probability of an accident. Other factors which were found to increase hazard at a crossing were the type of protection devices at the crossing and the type of environment (rural or urban). In some of the research, the type of environment (rural or urban) was classified into the two types with resulting factors for each while in other studies the type of environment was measured by a count of the number of distractions (number of buildings, billboards, etc.) within 500 ft of the crossing. Although the values of the factors differ for each method, it is clear that the type of environment (rural or urban, developed or undeveloped) at a crossing does influence the safety.

As to the type of protection and its effect on safety, the Voorhees study found that for train-vehicle accidents flashing signals reduced accidents at a crossing to 20 percent of what they were with only the present crossbuck and advance-warning techniques. The use of gates with flashing signals reduced accidents to 10 percent of the number with only crossbucks.

The use of such protective devices at crossings, of course, is expensive and certainly is not practicable or economical for many railway-highway grade crossings with crossbucks, where on the average only one vehicle-train accident will occur each 10 years. The practical approach to the railway-highway safety problem, therefore, is to establish a priority rating for each crossing in the total transportation system of an area and to upgrade the protection at locations where it will be of most value and where an economic analysis indicates that benefits exceed the costs.

Over the years a tool widely used in establishing priorities for grade crossing improvement has been the hazard index or priority index. The use of such an index provides a rational basis for decision making and minimizes the effects of emotional pressures and other influences on judgment. A number of such indexes have been developed over the years and recent research studies have added several more. One study in Lincoln, Neb., following an evaluation of several of these index formulas, found that the optimum index formula for Lincoln was one called the New Hampshire Formula. This formula includes three factors—vehicle volume, train volume, and type of protection factor. Equally important, however, was the finding that the results obtained from the 11 index formulas which were compared were similar. All 11 formulas could, therefore, be said to be all equally good or all equally bad. Although agreement has not been reached on one formula, it appears that such agreement is not really necessary. The use of one of the proposed formulas developed from past research will do a good job in assigning priorities for upgrading of protection. This is especially true if the final decision is also based upon an economic analysis of the costs and benefits likely to occur in each case.

In any event it is likely that many of the over 175,000 rail-highway grade crossings in the United States without a special type of protection will not warrant the installation of expensive gates or flashing lights or separation of grades. About 45,000 crossings have some form of special protection today.

In the Voorhees study, considerable effort was given to study of possible improvements at railway–highway grade crossings which would not warrant expensive special protection devices. Intensive study of signing practices, human factors involved and accidents at such crossings, together with an economic study of the problem, resulted in the design and testing of a number of new signs and possible practices. The study did find that a driver approaching a rail–highway grade crossing would be able to negotiate the crossing in a safer manner if he were provided more information than currently given him. Signs were therefore designed which would provide, through shape and message, at least one of the following types of information:

1. Inform the driver prior to the crossing exactly what his obligation will be (i.e., should he observe an automatic device which will inform him of a train's approach or is it his complete responsibility to look for approaching trains?).
2. Emphasize at the crossing when automatic devices are *not* present, that his responsibility is to determine the existence of trains in such proximity of the crossing as to constitute a hazard.
3. Provide him with additional information necessary for his safe negotiation of the crossing. For example, when sight distance is restricted and requires a speed reduction, post advisory speed signs. When the driver cannot see an approaching train sufficiently far in advance of the crossing, post reduced advisory speeds and tell him where and when on the approach to look.

The new signs tested were primarily classed as advance warning signs and were designed for placement on highway right-of-way on the approach to the crossing. Symbols were used extensively along with several sign shapes and colors. One new color for highway signs, brilliant yellow green, was used for some signs. The field tests resulted in recommendations from the researcher that the following signs deserved further testing:

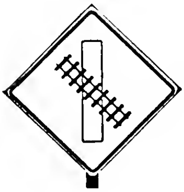
1. A new advance warning sign in the standard black-on-yellow diamond shape with a symbol message of a railroad crossing a highway.
2. A new supplemental advance warning sign in the standard black-on-yellow diamond shape with the message LOOK FOR TRAINS prior the point when the driver must see an approaching train in order to stop.

3. A new at-the-crossing sign of the railroad crossbuck sign on a large YIELD sign shape. The crossbuck would be black on white with a yellow background for the YIELD sign.
4. A new advance warning sign for crossings protected with active protection devices which would be shown in symbols on the standard yellow diamond shape. This sign would tell the driver he will be told if a train is approaching by active devices.

The four signs noted above are shown below.

RECOMMENDED SIGNS

PASSIVE PROTECTION

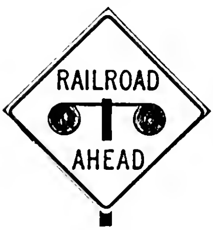


ADVANCE WARNING

SUPPLEMENTAL SIGN WHEN SIGHT DISTANCE IS INADEQUATE

AT THE CROSSING NEAR RIGHT AND FAR LEFT

ACTIVE PROTECTION



ADVANCE WARNING

NO CHANGE

AT THE CROSSING

Note:

Background color for all signs shown is standard highway yellow. Interiors of the two circles in the Active Protection Advance Warning sign are red symbolizing flashing lights at crossing.

Finally, note should be made of the December Grade Crossing Safety Symposium at Texas A&M University jointly sponsored by the Texas Transportation Institute and the U. S. Department of Transportation. The results of this symposium are in effect a good summary of the knowledge available today in the safety aspects of railway–highway grade crossings and of the needs which still exist in this area.

Important needs were noted as follows:

1. Advance warning to the motorist at an approaching railroad crossing and his responsibility throughout are today generally inadequate.
2. There is a need for the development of low-cost protective devices, of both the railroad-ahead warning type and train-approaching warning type.
3. Motorists need to be more impressed with the importance of the train-vehicle hazard.

Just as important as what we still need to learn is to know and apply what knowledge we already have. It is clear for example that the major factors affecting railway–highway grade crossing safety are the volume of vehicle travel, the volume of train travel, the type of protection employed and the environment of the crossing. It is also clear that information needed most by the motorist concerns itself with emphasis on his responsibility and with seeing an approaching train in time for him to stop. Anything that can be done to improve getting that information to him will improve safety at the crossing. The facts are also clear that many accidents occur at crossings which do not involve a train and that the factors causing these accidents also must be given consideration. The relative value of each type of protective device is also quite clear. The costs of installation and maintenance of each type of protective device and the reduction in accidents at a crossing from each improvement can also be estimated with sufficient accuracy to permit an economic evaluation to be made of each proposed installation. If we would apply the knowledge we have available, wise decisions on a transportation systems basis, can be made in the area of safety at railroad–highway grade crossings. Each agency, each person with responsibilities in this area must do no less.

(Applause)

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1. "Factors Influencing Safety at Highway–Rail Grade Crossings", Alan M. Voorhees and Associates, Inc., NCHRP Report 49, Highway Research Board, National Academy of Sciences, Washington, D. C.
2. "Evaluation of Safety at Railroad–Highway Grade Crossings", Thomas G. Schultz, Ph.D. Thesis, Purdue University, Lafayette, Ind., August 1965.
3. "Evaluation of Safety at Railroad–Highway Grade Crossings in Urban Areas", William D. Berg, MSCE Thesis, Purdue University, Lafayette, Ind., January 1967.
4. "Optimum Hazard Formula for Railroad Crossing Protection for Lincoln, Nebraska", Georgy Bezkorovainy and Robert G. Holsinger, Traffic Engineering Department, Lincoln, Neb., February 1967.

Chairman Dejaiffe: Thank you, Professor Michael, for a very informative talk about recent research on highway–railway grade crossing safety. We appreciate this talk on a subject that I'm sure will become very important before our next report to this convention, a year from now.

My three years as chairman of Committee 9 end at the closing of this convention. While there were times when I wondered how I was ever going to meet the many deadline dates, it has been an honor to serve as chairman. There was extra work involved, but I assure you I was more than repaid for my efforts in additional knowledge which was valuable both to me and my railroad. I thank all of the members of the committee for their loyal support and for the pleasure of working with them. Thanks also are due to the officers of the Association and to the executive secretary's staff for their wise guidance, help, and for their interest in our work.

My last duty as chairman is a pleasant one. I would like to introduce the vice chairman and chairman of Committee 9 for the next three years. I am sure the committee will be in good hands under their capable leadership.

The new vice chairman is K. E. Wyckoff, assistant chief engineer—staff, Great Northern Railway.

The new chairman is R. E. Skinner, assistant to chief engineer, Illinois Central Railroad, who was unable to be present today because of conflicting railroad duties.

Mr. President, that concludes our report.

President Hutcheson: Thank you, Mr. Dejaiffe, and your committee for your usual fine and informative reports. Your area of responsibility is extremely important in the time in which we live.

Professor Michael, your appearance here today is another in a long interaction between AREA and Purdue University. We thank you for that talk emphasizing safety at grade crossings. We fully recognize the importance of this entire subject and appreciate having you point out to us the basic problems. But how are we ever going to overcome the human factor of the "nut" behind the wheel?

I am told there is a highway crossing sign somewhere in the Chicago area that reads something like this:

"A train takes 15 seconds to move over this crossing—whether your automobile is on it or not."

Again, Professor Michael, thank you for your continued efforts on behalf of the Association.

Mr. Dejaiffe, we appreciate the able and dedicated leadership which you have given to Committee 9 for the past three years. As you are relieved of your responsibilities as chairman, we are pleased to welcome Mr. Skinner as your successor, and Mr. Wyckoff as the new vice chairman of the committee. We are satisfied from their past performance that under their direction the important work of Committee 9 will continue.

It would now be my duty, if he were here, to present Mr. Skinner with a gavel to indicate his new authority as committee chairman. We will, of course, send it to him. The inscription on the gavel reads:

"R. E. Skinner, Chairman AREA Committee 9, 1968–1970."

Mr. Dejaiffe, your committee is now excused with the thanks of the Association. (Applause)

Discussion on Economics of Railway Location and Operation

(For report, see Bulletin 609, pages 125–142)

President Hutcheson: Gentlemen, we will now receive the next to the last report to be presented at this session. It will be given by Committee 16—Economics of Railway Location and Operation. The chairman of this committee is L. E. Ward, senior system industrial engineer, Penn Central Company, Philadelphia, Pa.

Mr. Ward, you may now proceed with your committee report.

Chairman L. E. Ward: President Hutcheson, members and guests of the Association:

Committee 16 directed its efforts to nine assignments related to the "economics of railway location and operation" this year.

Reports reflecting the results of our work may be found in Bulletins 607, 608, and 609. These include comprehensive reports on five assignments. I would like each of the chairmen of the subcommittees responsible for these particular reports to stand and accept recognition for the work their subcommittee has done.

Assignment 2—Engineering Methods and Economic Considerations Involved in Improving the Quality of Transportation Service. Chairman: W. J. Dixon, vice president—executive department, Chicago, Rock Island & Pacific.

Assignment 4—Potential Application of Electronic Computers to Railway Engineering and Maintenance Problems in Research, Design, Inventory, Etc. Chairman: G. W. Guthrie, director of corporate planning, Soo Line.

Assignment 6—Features of Economic and Engineering Interest in the Study, Design, Construction and Operation of New Railway Line Projects, or Major Line Relocations, Proposed, in Progress, or Recently Completed. Chairman: H. L. Woldridge, assistant chief engineer—planning and scheduling St. Louis–San Francisco.

Assignment 7—Application of Industrial Engineering Functions to the Railroad Industry. Chairman: F. A. Koomanoff, senior associate, Planning Research Corporation.

Assignment 8—Investigate the Use and Value of Network Analysis and Make Appropriate Recommendations for Its Application to Railway Functions. Chairman: W. G. Byers, assistant engineer, Santa Fe.

Chairman Ward (continuing): We are progressing four other assignments. For these, I would like for the chairmen to stand and be recognized.

Assignment 1—Revision of Manual. Chairman: G. Rugge, special assistant–staff studies, Santa Fe.

Assignment 3—Determination of Maintenance-of-Way Expense Variation with Various Traffic Volumes and Effect of Using Such Variations, in Terms of Equated Mileage or other Derived Factors, for Allocation of Available Funds to Maintenance-of-Way. Chairman: H. B. Christianson, director of industrial engineering, C&O–B&O.

Assignment 5—Location and Operation of Metropolitan Transit Systems as Related to Current Railway Operations. Chairman: L. A. Durham, assistant chief engineer–staff, Norfolk & Western.

Assignment 9—Determine the Additional Costs for Construction, Operation and Maintenance That Are Incurred in Upgrading Present Main Tracks to Support Very High Sustained Speeds Above 80 MPH. Chairman: W. B. O'Sullivan, manager of production, Boston & Maine.

Chairman Ward (continuing): While all our assignments and resultant reports have been creative and informative, three of them deserve further amplication at this time.

First, Mr. Dixon will highlight his report on Quality of Service.

Assignment 2—Engineering Methods and Economic Considerations Involved in Improving the Quality of Transportation Service

W. J. Dixon: Subcommittee 2's assignment on "Engineering Methods and Economic Considerations Involved in Improving the Quality of Transportation Service" focuses on one of the foremost challenges facing the railroad industry today. The subject of quality control for railway service is one to which the engineer can make an important contribution, both in carrying out his own responsibility for an adequately constructed, well maintained, and efficiently operated system and in assisting other departments primarily concerned with marketing the railroad's product.

The subcommittee has selected for review four general categories of transportation quality relating to railroad service: (1) time, (2) car condition and availability, (3) prevention of loss and damage, and (4) special services. I should like to address your attention briefly to the second category—car availability—which is a natural outgrowth of car utilization. Our most recently published report, entitled "The Potential for Improvement in Freight Car Utilization," authored by one of our members, John R. Wilmot, appeared in the September–October 1967 Bulletin No. 608. Mr. Wilmot used various yardsticks to compare car utilization of railroads in the United States with that of roads in various other advanced countries and concluded that many opportunities remain for railroads throughout the world to make more productive use of their freight car fleets.

The ability to improve car utilization is doubly beneficial—it increases the car supply to the shipper, and it increases the rate of return on equipment investment to the railroad. The latter assumes critical importance when it is remembered that equipment constitutes nearly half the total railroad investment.

In the pursuit of these objectives, a number of railroads in recent years have been taking calculated steps to achieve increased car utilization. Some of these steps have included:

(1) Computer information systems for use in the control of car movements, both loaded and empty.

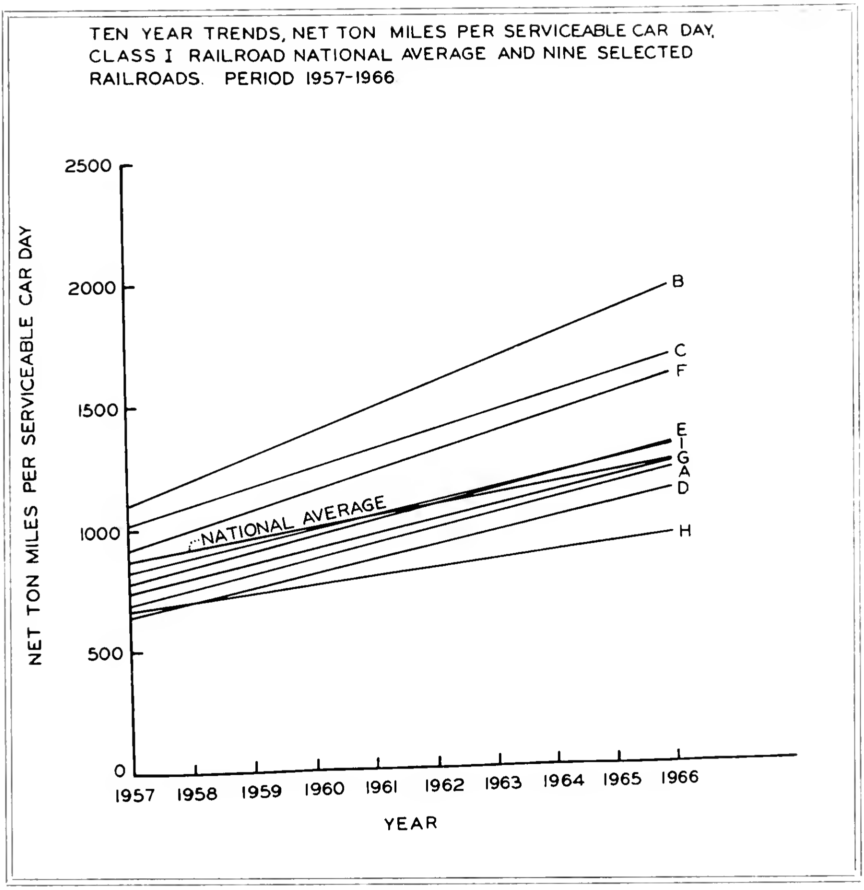
(2) Centralized car distribution.

(3) Application of linear programming to car distribution.

(4) New techniques to expedite car cleaning and car repairs.

(5) Terminal control systems.

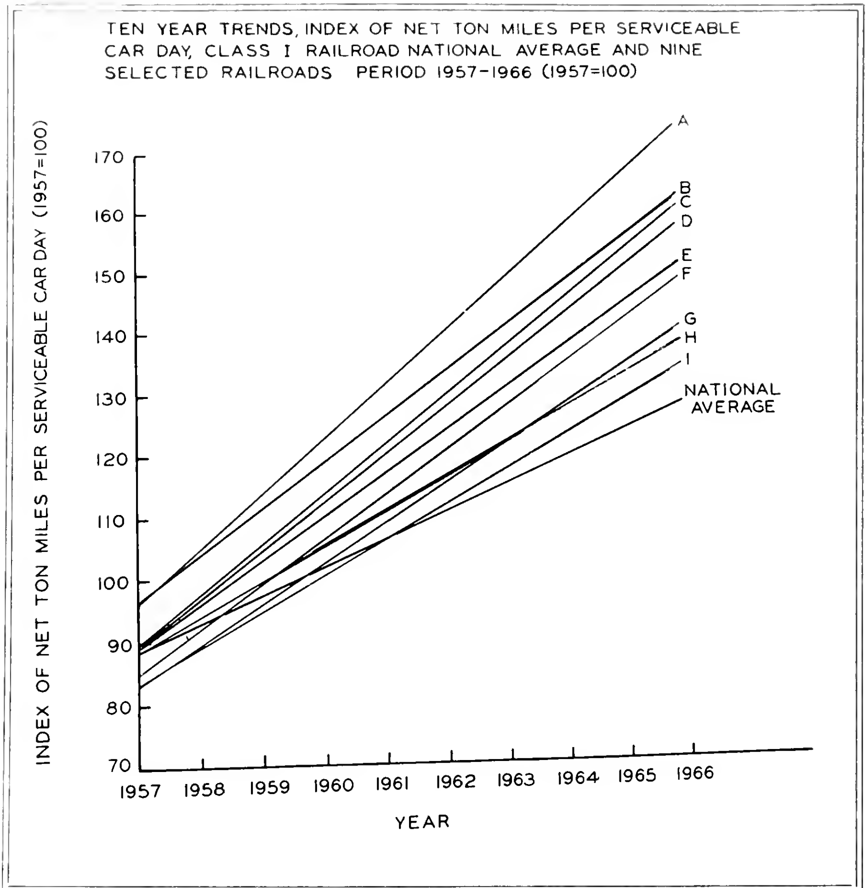
As a result of steps of this kind, the productivity of freight cars on a number of major railroads, measured in net ton-miles per serviceable car day, has increased over the past ten years at a rate substantially in excess of the rate of increase of Class I railroads as a whole. On graph 1, regression trend lines of absolute values of net ton-miles per serviceable car day for Class I railroads and nine selected railroads are shown over the decade ending in 1966. On graph 2, the regression trend lines of the indices of these values, with 1957 equal to 100, are shown. It will be noted that while net ton-miles per serviceable car day for all Class I roads have increased 34.3 percent during this period, some roads have experienced increases



Graph 1

of almost twice this amount. The general improvement shown by Class I railroads reflects the nationwide increase in load per car (as car capacities increased and loads followed) and in miles per loaded freight car day. The performance of the individual roads shown had the effect of expanding the size of the national car fleet in 1966 by the equivalent of some 122,000 cars, representing a growth in capacity which would not have been available to handle the nation's traffic had their car productivity increased only to the extent of that of all other railroads.

Of course, car utilization is just one facet of the problem. Our fellow committee member, Dr. Lewis K. Sillcox, points out that quality control of services is an essential ingredient if the railroads are to fulfill their role as purveyors of dependable, time-oriented, damage-free, door-to-door service on a wholesale scale and in sufficient volume at compensatory rates to remain competitive and technologically viable. This means that standards of acceptability must be established and maintained in



Graph 2

every phase of the railroads' operations, against which management and customer alike can measure the quality of service provided. Subcommittee 2 will continue to direct its studies toward the attainment of these goals by the railroad industry.

CHAIRMAN WARD: Thank you, Mr. Dixon. We feel rather strongly in this committee that the railroad industry is a service industry, and as Mr. Lang, one of our members, pointed out this morning, we feel this is a job for the engineers to tackle. If we don't, I am not sure who will, and we sort of feel maybe we, as an industry group and as a professional group are the best qualified to tackle it.

Assignment 6—Features of Economic and Engineering Interest in the Study, Design, Construction and Operation of New Railway Line Projects, or Major Line Relocations, Proposed, in Progress, or Recently Completed

CHAIRMAN WARD: Committee 16 has presented papers on line relocation covering a wide scope of types of projects. While we find there is an increasing number of new line and line relocation projects being undertaken, with exciting new methods being employed, we hope we have exposed the essential factors involved to a sufficient degree to permit us to move on to new assignments. I have asked Mr. Woldridge, chairman of Subcommittee 6 to summarize this assignment.

H. L. Woldridge: Mr. President, Chairman Ward, ladies and gentlemen:

Subcommittee 6 of Committee 16 was organized in 1960 with the primary responsibility to present to the Association the features of economic and engineering interests in the study, design, construction and operation of new railway line projects, or major line relocations, proposed, in progress or recently completed. Since then, the following reports on this asignments have been published.

Bulletin 560, November 1960, "The Pea Ridge Railroad Location;" describes the construction of a 27-mile rail line to serve new iron mines in Central Missouri. It was constructed by the Missouri Pacific Railroad. Also in this same Bulletin, there is described the "Construction of Beattyville Chibougamau Branch Line," a 155-mile new line in Northern Quebec to serve ore fields in that district.

Bulletin 567, November 1961, "Vancouver to Squamish and the Peace River Extension on the Pacific Great Eastern Railway;" describes 365 miles of construction in British Columbia to aid development in that region. This same Bulletin includes a report on "Santa Fe Relocation of Main Line in Arizona," which covers the construction of a 44-mile double-track railway to provide more economical operation.

Bulletin 574, November 1962," Keystone Dam Relocation, St. Louis–San Francisco Railway;" describes a 17-mile relocation necessary due to the construction of a flood control reservoir on the Arkansas River near Tulsa, Okla. The same Bulletin includes a report on "Photogrammetry as Applied to Railway Location," covering locations in Canada and West Africa; also in the same Bulletin the "Abra-Skull Valley Relocation in Arizona by the Atchison, Topeka and Santa Fe Railway," is described. This work was done to provide better service for the expanding population of Central Arizona.

Bulletin 581, November 1963, "Potash Spur on the Denver & Rio Grande Western Railway;" describes a 36-mile spur constructed in Utah to serve newly developed potash fields.

Bulletin 587, September–October 1964, describes "Construction of the Great Slave Lake Railway" in Northern Alberta. This is a 430-mile line constructed to aid in the development of that region.

Bulletin 594, September–October 1965, "Eufaula Dam Relocation—Missouri–Kansas–Texas Railroad," describes construction of a 21-mile relocation in Central Oklahoma necessitated by the construction of the Canadian River Reservoir near Eufaula, Okla.

Bulletin 601, September–October 1966, "Barkley Dam Relocation, Illinois Central Railroad," describes 16-mile main-track relocation at the Barkley Reservoir on the Cumberland River in western Kentucky.

For these publications we are indebted to George Sowers, formerly assistant construction engineer of the Missouri Pacific Railroad; J. C. Martin, terminal design engineer, Canadian National Railways; J. L. Charles of the Canadian National Railways; J. A. Inman, assistant engineer, Atchison, Topeka and Santa Fe Railway; George Rugge, special assistant, staff studies, Atchison, Topeka & Santa Fe Railway; E. H. Waring, chief engineer, Denver & Rio Grande Western Railway; A. N

DeMaret, engineer, Missouri–Kansas–Texas Railroad; and W. W. Arnett, project engineer, Illinois Central Railroad.

The construction and relocation projects described are not all of the railroad relocations and construction that took place during this period, but are typical of what was being done. These particular projects can be roughly divided into three groups: (1) relocations made necessary because of large reservoirs resulting from flood control dam construction, (2) new construction to aid in industrial development, and (3) relocation construction for more economical operation. In the future it is anticipated that there will be many more relocations, particularly where more economic operation can be accomplished. No doubt future high-speed rail transportation will require many miles of relocation and new construction.

Finally we come to two reports appearing in Bulletin 608, September–October 1967. The first entitled "Construction and Operation of a Spur Track Built on a 5.6-Percent Grade to Serve the Boeing Company near Everett, Washington" appears on pages 78 to 82. Prepared by T. C. Nordquist, principal construction engineer, Great Northern Railway, this report describes how a 1.7 mile spur was constructed in a narrow, steep-sided, heavily wooded ravine on a 5.6-percent grade, with a maximum curvature of 13 deg., in order to reach the Boeing Company's 747 Transport Plant located adjacent to a large airport. The track gradient gave the operating people a problem also which made it necessary to select the SD-9 type locomotive for this operation. Certain trainmen and enginemen were especially qualified to operate trains on the spur. It was necessary to have the caboose on the high end of the train, both ascending and descending grade, operating at maximum speed of 10 mph.

It is apparent from this report that, to get new business, the railroad industry might take another look at its design criteria for grade and curvature in track construction and development.

On January 21, 1968, a Springfield, Mo., newspaper carried an AP release date lined Dar-es-Salaam, Tanzania, entitled "Commie China Pushing Its Way into Africa with Railway Plan—Rail Link of Zambia—Tanzania."

This is the same railroad route described in the second report in Bulletin 608, pages 82 to 95, prepared by J. L. Charles, Consultant on Railway Location, entitled "Proposed Zambia—East Africa Rail Link: British–Canadian Survey 1966."

Mr. Charles in his report outlines the history of railroads and their routes in south–central Africa, wherein Rhodesia Railways operate from the Atlantic Ocean Port of Lobito, Angola easterly and southerly through the Congo, Zambia, Rhodesia and thence easterly through Mozambique to the port of Beira on the Indian Ocean. East African Railways and Harbours operates from the Indian Ocean part of Dares-Salaam, Tanzania, inland west and north to Uganda. Thus there is a 980 mile gap between the Rhodesia Railway in Zambia and the East Africa Railways in Tanzania. If these two systems could be linked across the common border of these two countries, Zambia would have an alternate and shorter route to the Indian Ocean through country controlled by Africans.

Since a rail link would also open up new marketing centers in both countries, through traffic would permit exporting copper, lead and zinc and importing petroleum products, mining and agricultural equipment, etc. Transport to and from intermediate stations would be agricultural and forest products.

General reconnaissance was carried out from light aircraft. Then closer observations were made from helicopter and on the ground. As the route was established, aerial photography was obtained and surveys were run to set ground control stations.

Estimates of cost to construct the proposed railway together with expenditures to change the gage and improve a portion of the East Africa Railway, to expand port facilities, and purchase equipment required to put the project into operation, as well as the annual cost of maintenance-of-way and operation and expected revenues, were submitted to the Inter-Governmental Committee of Zambia and Tanzania.

Mr. Charles further states that a report from Lusaka, Zambia, July 4, 1967, is interesting: "China has agreed to finance and build a planned $300,000,000 railway between Zambia and Tanzania, President Kaunda of Zambia told a press conference on July 5. He said that before a final decision is taken, replies from four countries approached for aid for the railway—the United States, Britain, France, and Japan—will be examined."

The newspaper article of January 21 states "An agreement with Tanzania and Zambia was made at Peking in September 1967. Tanzania's financial minister said it provided for an interest-free loan of 100 million pounds, then equal to 280 million dollars, to finance and build the railway. The president of Tanzania said "It is not as if we had alternative proposals to choose from. We should indeed have welcomed western offers, but the only firm offer we had was from China."

Under these circumstances it will be an interesting project to watch develop.

Mr. President this is the final report on Assignment 6.

Assignment 8—Investigate the Use and Value of Network Analysis and Make Appropriate Recommendations for Its Application to Railway Functions

Chairman Ward: Network analysis is an engineering tool which has been around for many years in the electrical engineer's tool kit, and another type of network analysis has evolved in the form of CPM or PERT; however, much knowledge is yet to be learned regarding use of network analysis for solving complicated transportation engineering problems. Mr. Byers will attempt to stimulate your thinking on the use of network analysis.

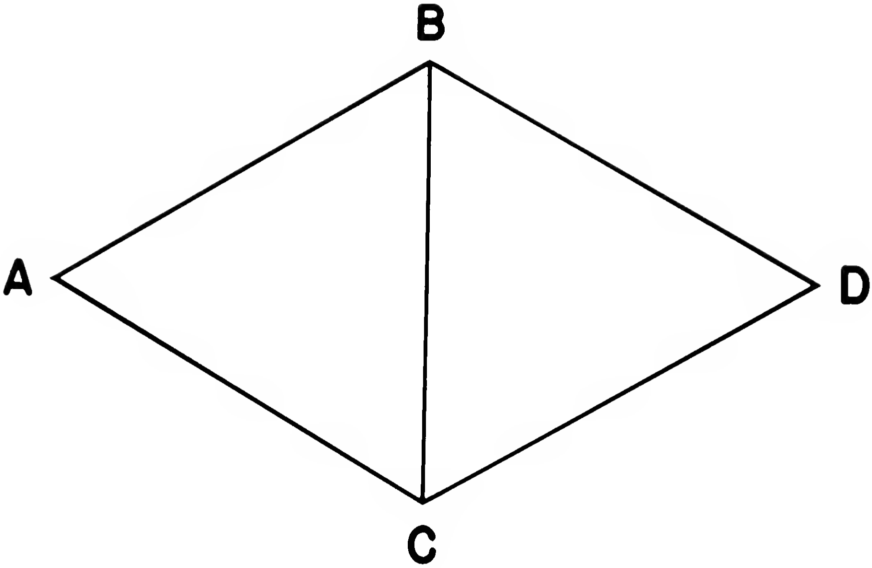
W. G. Byers: Mr. President, members and guests:

Last year Committee 16 received the assignment of investigating applications of network analysis to railway functions. Subcommittee 8's published report on this assignment was written as an introduction for AREA members who are not expert in the subject but might at some time have a need for a general understanding of network analysis techniques. This report discussed a few applications in general terms and included a list of references for the benefit of anyone wishing to pursue the subject further.

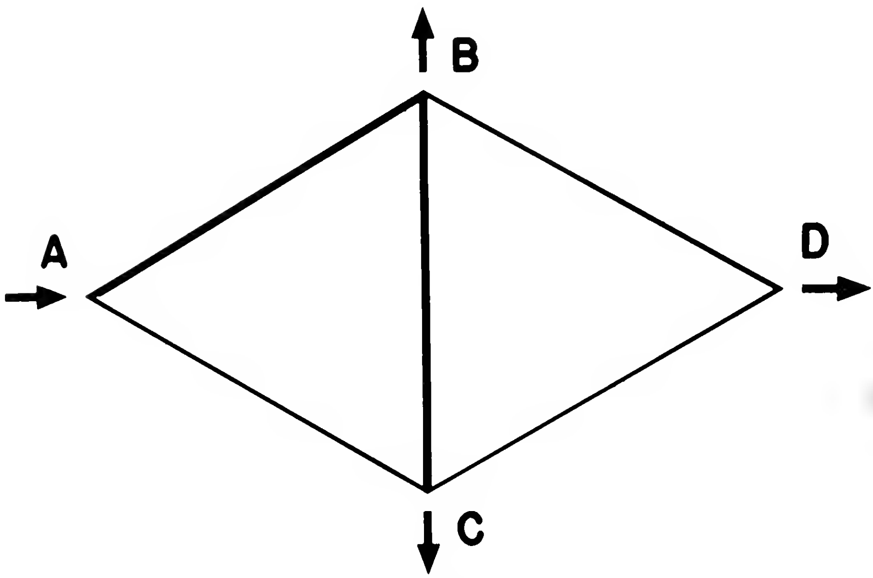
The AAR Data Systems Division is also working in the area of network analysis and is about to request bids for development of a railroad network simulation program. The Canadian National is working on a network simulation program. The Frisco spent about 5 man-years of highly qualified talent developing such a program. The Department of Transportation has awarded Northwestern University a $200,000 contract for simulation of interaction between various modes of transportation in the Northeast Corridor. The Frisco and Department of Transportation efforts give an indication of the complexity of the problems involved.

What is a network and how can the average AREA member use network analysis?

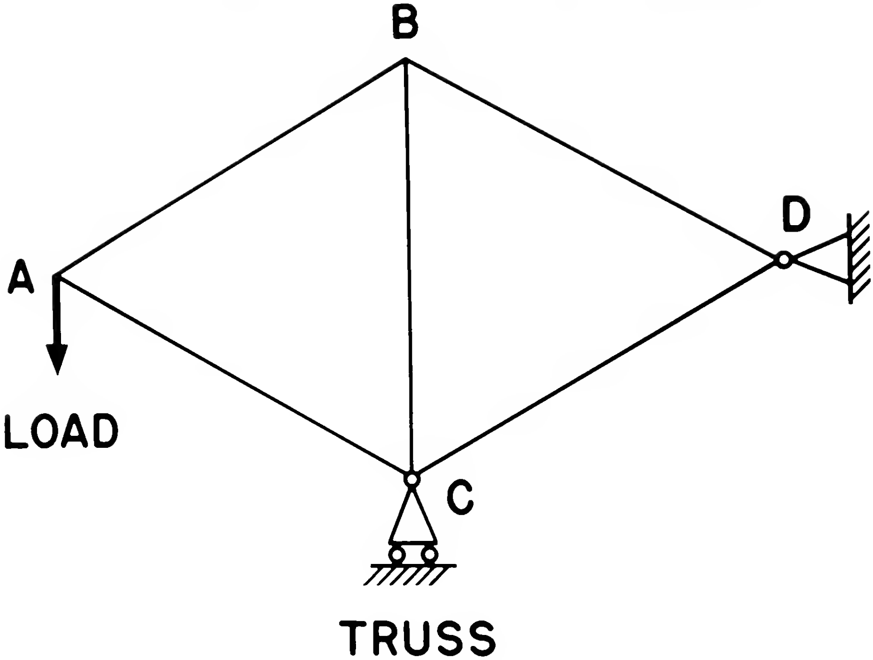
(Slide 1) This slide shows a network defining the relationships between A, B, C and D. The points A, B, C and D may be points in a physical network, such as



Slide 1



Slide 2



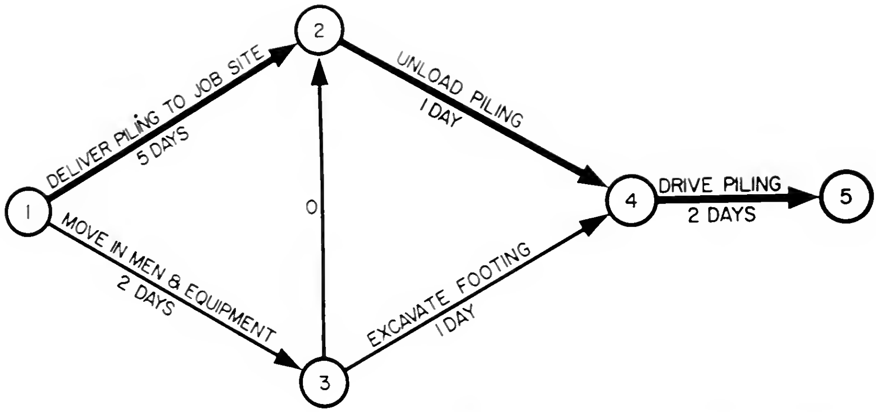
Slide 3

junctions on a railroad, interchange points between railroads, or joints in a pipe system or a structure, or they may be items related logically rather than physically. This is an unusually simple network but will serve to illustrate some possible applications of network analysis.

(Slide 2) In a pipe network the direction and volume of flow are uniquely determined by the laws of hydraulics plus two laws for networks. (1) The head loss between two points such as A and B is the same regardless of the path followed between them. (2) At any instant the flow into a joint equals the flow out of the joint. By comparison a railroad network is infinitely more complex because many types of flow, including empty cars and various kinds of loads, can occur at once, and flow can be in both directions at the same time over a single path. In such a problem, the solution is not defined by physical laws.

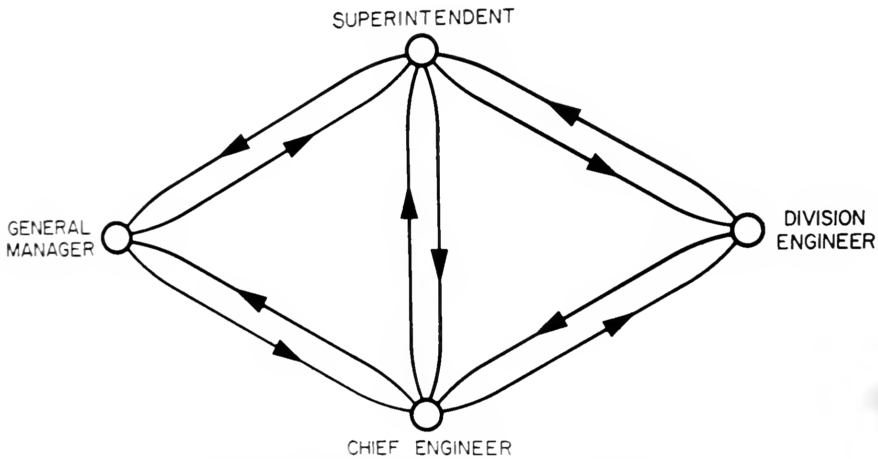
(Slide 3) In this case the network represents a structure. The forces and moments in the members are determined by the laws of mechanics plus two laws applicable to networks. (1) The displacement of any point in the structure relative to any other point is the same regardless of the path followed around the structure in going from the first point to the second point. Otherwise there would be a rupture in the structure. (2) At any joint all the loads and forces are in equilibrium.

(Slide 4) In some networks the direction of flow is not controlled by physical laws but is predetermined. The network now represents a critical path diagram for driving foundation piling. Nodes at 1, 2, 3, 4 and 5 represent events and the lines connecting them represent activities.



CRITICAL PATH DIAGRAM FOR PILE DRIVING

Slide 4



ORGANIZATION CHART

Slide 5

(Slide 5) If the flow between two points can occur in both directions rather than in only one direction, the points can be connected by two directed lines. In the simple organization represented on the slide, one of the two lines represents the flow of instruction or commands and the other represents the flow of information or feedback. When communication breaks down the network is changed.

A network can represent connecting paths in a physical system or it can represent a system of logical relationships. It can be simple or complex depending on the number and nature of the relationships. For a complex system, a computer is usually necessary to solve the problem in a reasonable length of time. In some cases the computer aids in solving the network problem. In other cases the expression of relationships by the network aids in developing the computer program. For less complex problems, network analysis often provide a tool for defining the problem and can point the way to a solution. This last use may well be the most valuable one for most of us.

If either this report or the subcommittee's published report has encouraged any AREA members to successfully use a network approach to the solution of any problem, the work of the subcommittee during the past year has been worthwhile.

(Applause)

Chairman Ward: In addition to expressing my personal thanks to all the members of Committee 16 for their work during the last year, I would like to have our secretary, Bob McKnight, editor of Railway Signaling and Communications, stand and be recognized.

Are there any questions concerning any portions of our report? If not, Mr. President, this concludes the report of Committee 16.

President Hutcheson: Mr. Ward, thank you for the work of your committee and for the efforts of yourself and the members of your committee on behalf of the Association.

Your committee is now excused with the thanks of the Association.

Discussion on Waterways and Harbors

(For report, see Bulletin 610, pages 253–266)

President Hutcheson: The last committee on today's program is Committee 25—Waterways and Harbors, the chairman of which is G. R. Collier, project engineer, Atchison, Topeka & Santa Fe Railway, Topeka, Kans.

Mr. Collier, the microphone is yours as soon as you are ready.

Chairman G. R. Collier: Thank you, Mr. Hutcheson. Committee 25—Waterways and Harbors, has been working on four assignments.

Assignment 2—Current Policies, Practices and Developments Dealing with Flood Control, Water Conservation, Waterways and Water Navigation Projects, is under the chairmanship of George E. Anderson, engineering analyst of the AAR Research Department. He is an exceptionally able chairman for that subject, but he could not be here today.

Assignment 3—Bibliography Relating to Benefits and Costs of Inland Waterway Projects Involving Navigation, is under the chairmanship of W. D. Phelps, utilities engineer of the Chicago, Rock Island & Pacific at Chicago. He likewise is absent

Assignment 6—Planning, Construction and Maintenance of Rail–Water Transfer Facilities, was under the chairmanship of R. L. Pettegrew, manager, Freight Transportation Planning, The Port of New York Authority. He was here but had to leave.

Assignment 7—Relative Merits and Economics of Construction Materials Used in Waterfront Facilities, is under the chairmanship of Dr. Shu t'ien Li, professor, Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, S. Dak. Dr. Li is also absent.

Assignment 2—Current Policies, Practices, and Developments Dealing with Flood Control, Water Conservation, Waterways and Water Navigation Projects

CHAIRMAN COLLIER: In the absence of Mr. Anderson, L. H. McCurry, assistant engineer for the Santa Fe at Amarillo, Tex., will now present the report on Assignment 2.

L. H. MCCURRY (for Subcommittee Chairman G. E. Anderson): Mr. President, members and guests:

The report on Assignment 2 appears on pages 254 through 266 of Bulletin 610. It consists of a summary of the various transportation benefit evaluation procedures that have been adopted for determining the advisability of Federally constructed inland waterway projects for commercial navigation. The report indicates from May 1950 through June 1967 a total of ten transportation benefit evaluation procedures were adopted. Five were issued by the Corps of Engineers, two were prescribed by the Executive Office of the President, two were proposed by the Federal Inter-Agency Committee on Water Resources, and one was established by an Act of Congress. A description of the three basic types of transportation benefit evaluation procedures is supplemented in the report by extensive quotations from the procedures presented in ten U. S. Government publications.

These references are listed in Table 1 of the report; however, the page numbers for the benefit evaluation procedures were omitted and are as follows:

"Current Rate" Procedures		Cost of Providing the Service Procedures		"Projected Rate" Procedures	
Reference*	Page No.	Reference*	Page No.	Reference*	Page No.
A-1	292–301, 311, 312	C-1	46–49	A-3-b	40a, 40b
		B-1	8, 10	A-5	1–3 and A-1 thru A-12
A-2	37, 38	C-2	40, 41		
D-1	12	A-3-a**	39, 40, 40a		
A-4	1–5	B-2	9–11		

* As identified in Table 1, Bulletin 610, December 1967, page 255. Listed here in sequence according to the publication date. "A" denotes procedure issued by the Corps of Engineers, "B"—the Executive Office of the President, "C"—Federal Inter-Agency Committee on Water Resources, and "D"—Act of Congress.

** Incorrectly listed as reference A-4 on page 262, Bulletin 610.

The extent to which the economic justification of inland waterway projects is dependent upon the procedure used to estimate the transportation benefits was clearly indicated in the Corps of Engineers' January 1965 survey report on the Lake Erie–Ohio River Canal project. The transportation benefit estimates for each of the three basic procedures as presented in Appendix IX of the survey report are as follows:

Procedure for Evaluating Navigation Benefits	Average Annual Navigation Benefits	Benefit to Cost Ratio
Current Rates	$138,160,000	3.12
Projected Rates	87,510,000	2.19
Cost of Providing the Service	10,100,000	0.76

The transportation benefits using the "projected rate" and "current rate" procedures are nearly 9 and 14 times greater, respectively, than the benefits obtained by the "cost of providing the service" procedure. As stated in the Corps' report, "the project would not produce sufficient benefits to warrent its construction"—if judged on this cost comparison basis.

The purpose of this report on Assignment 2 was to describe and document the various transportation benefit evaluation procedures objectively without comment or discussion regarding either the merits or weaknesses of the various procedures. Your committee has taken no position one way or the other regarding the quotations given on page 264 of the report, which present the Corps of Engineers' reasoning for rejecting both the "current rate" and "cost of providing the service" procedures for determining the advisability of constructing the proposed Lake Erie–Ohio River Canal. Your committee merely considered these quotations to be important background information regarding the adoption of the "projected rate" procedure. The Corps' January 1965 report on this project represented the first departure of the Corps from the "current rate" procedure and was also the first report to mention the "cost of providing the service" procedure.

The last sentence on page 264 of the report regarding the termination of the "projected rate" procedure is incomplete and should be replaced by the following:

Use of the procedure was terminated as of May 1966 upon the recommendation of the Chief of Engineers and concurrence by the Director of the Bureau of the Budget with the expectation that the Chief of Engineers would issue new instructions in a few weeks to implement the cost basis of evaluating waterway benefits. This change in procedure was confirmed by a directive from the Bureau of the Budget dated August 24, 1966, which stated:

Chairman Collier: As I said a little while ago, Mr. Pettegrew had to return to New York. I would like to introduce the man who will serve as chairman of Subcommittee 6 for the coming year—W. E. Corbett, harbor engineering associate, Port of Long Beach, Calif. Mr. Corbett, will you stand, please.

Motion Picture, "Today the 21st," Produced by the Port of New York Authority

Chairman Collier: John Gressitt of the South Carolina State Ports Authority will now introduce our special feature—a film on container handling at the Port of New York. Mr. Gressitt.

John Gressitt: Mr. Chairman, directors and members of AREA:

The film you are about to see is entitled "Today the Twenty First." Its title refers to the fact that the changes in transportation which are taking place today are so revolutionary as to make one think of the next century. While this film was prepared and produced by the Port of New York Authority, Committee 25 is showing it today, not to promote specifically the physical facilities and transportation services available at the Port of New York, but to demonstrate container technology which is having an impact on marine transportation comparable to that which occurred with the transition from sail to steam. In this film you will see examples of both full containerships and combination ships lifting both containers and break-bulk cargo.

I would like to say a few words about the economics of the full containership and the effect it is having on ocean transportation and thereby also on rail transportation. The full containership and the ancillary port facilities needed to service it are extremely expensive. The goal of every full containership operator, therefore, is to keep this investment productive by minimizing costly in-port time. This is accomplished primarily by means of the extremely rapid discharge and loading capabilties available with a containership. For example, with a break-bulk cargo ship working five hatches with five gangs, the nominal productivity rate would be on the order of 100 tons per hour. In contrast, a full containership utilizing but two gangs can handle upwards of six times that tonnage, or 600 tons per hour.

This speed of discharge and loading has an important secondary effect—it is becoming much more important to accumulate larger quantities of cargo at any given port of call in order to spread the high fixed costs of facilities and the nonproductive in-port time over a larger amount of tonnage.

In terms of ports, this means that the full containership can no longer afford call at five or six ports at each end of the ocean voyage but rather the cargo will be accumulated at a much smaller number of ports, perhaps no more than two ports at each end of the voyage.

This characteristic of the containership is being demonstrated on the east coast where many major steamship lines other have already announced, or are considering announcement of, plans to eliminate service at many traditional major east coast ports.

We expect this trend to continue, and to the extent that it does, it is obvious that the railroads which handle large volumes of import/export freight will be affected in that more and more tonnage will be funneled through a smaller number of ports than has been the case heretofore. It is entirely conceivable that in the not too distant future we may see this trend develop into the operation of entire trainloads of import/export freight in containers moving between major inland manufacturing–distribution points and a seaport. Additionally, with comparable advances in railroad handling and movement of containers, we very well may see the initiation in the United States of coast-to-coast container trains which, in effect, will substitute inland transportation for the longer voyage via the Panama Canal. This is the so-called "Land/Bridge" concept which you have undoubtedly read about or heard about in recent months. Interestingly enough, the USSR has already instituted such a service across Siberia as a link between Japan and Europe.

Without further delay, we would like to show you "Today the Twenty-First," pointing out only that while this film was produced only about a year ago, it is in some areas, already obsolete. For example, two of the ship lines serving New York have already announced that they will no longer provide ocean transport on the Atlantic because of the intense competition being provided by the full containership. I hope you will enjoy the film.

(The film was then shown).

(Applause)

Chairman Collier: Mr. President, that completes the presentation of Committee 25. And the completion of this convention will see the end of my term as chairman of Committee 25. It is now my privilege to introduce the new officers who will be guiding this committee for the next three years. I am sure they will do it very well.

The vice chairman will be L. H. McCurry, assistant engineer, Atchison, Topeka & Santa Fe Railway.

The chairman will be J. C. Fenno, assistant division engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Milwaukee, Wis., who, as vice chairman during the past three years, has given me valuable assistance.

President Hutcheson: Thank you, Mr. Collier, for your report and the interesting motion picture.

The Association deeply appreciates the dedicated leadership which you have given Committee 25 over the past 3 years. As you are relieved of your responsibility as chairman, we are pleased to welcome Mr. Fenno as your successor and Mr. McCurry as the new vice chairman of the committee. We are satisfied from their past performance that under their direction, the work of Committee 25 will continue in good shape.

Mr. Fenno, as a symbol of your new authority and to assist you in conducting the meetings of your committee, I would like to present you with this chairman's gavel. The inscription reads:

"J. C. Fenno, Chairman AREA Committee 25, 1968–1970."

(The gavel was presented to Mr. Fenno.)

J. C. Fenno: Thank you very much, Mr. President. I will do everything I can, and with the splendid cooperation of the other members of the committee we will maintain the high standards of the Association.

President Hutcheson: Mr. Collier, your committee is now excused with the thanks of the Association.

(Applause)

President Hutcheson (continuing): Gentlemen, this concludes the first general session of our 1968 convention. We thank you for your attendance and hope that you have gained much from the deliberations and discussions at this session. I have just been informed that up to the present time, 2,338 men have registered, only 119 short of the record attendance in 1965, and we still have 1½ days of registration ahead of us.

Our convention now stands adjourned until 9:00 o'clock tomorrow morning. May I remind you that part of the first presentation tomorrow is an illustrated panel discussion on "Clearances and Problems Involved in Computerizing Them," sponsored by Committee 28—Clearances. I will look forward to seeing you in the morning.

(The meeting recessed at 5:10 o'clock.)

Morning Session, March 20, 1968

(The meeting reconvened at 9:00 o'clock, with President Hutcheson presiding).

President Hutcheson: Good morning, gentlemen: Will the second General Session of the 1968 convention please come to order. The first committee to report this morning will be Committee 28—Clearances, the chairman of which is J. A. Crawford, assistant office engineer, Chesapeake & Ohio Railway—Baltimore & Ohio Railroad, Huntington, W. Va. This morning the General Session will be conducted by H. E. Wilson, vice president, AREA, and assistant chief engineer system, Atchison, Topeka & Santa Fe Railway, Chicago.

(Mr. Wilson assumed the chair.)

Vice President Wilson: Thank you, Mr. President. Before turning the microphone over to Chairman Crawford, I want to again extend to each of you the privilege of the floor and invite your comments on, or criticism of, any of the report presentations, within the time which can be allowed for discussion. When you desire to speak, please address the chair, state your name and railroad or company clearly for the benefit of our convention reporter and then proceed with your comments or questions.

Mr. Crawford, you may now proceed.

Discussion on Clearances

(For report, see Bulletin 610, pages 267–276)

Chairman J. A. Crawford: Mr. Vice President, members of the Association, and guests:

The report of your committee was published in Bulletin 610, December 1967, on pages 267 through 276. It covers four out of six of your committee's then standing subjects.

Your committee solicited—and still solicits—comments on the Special Notes and Diagrams in its Report on Assignment 1—Revision of Manual.

In its Report on Assignment 2—Compilation of the Railroad Clearance Requirements of the Various States, a chart is included which shows these clearance requirements. Any knowledge by the membership of this Association relative to changes in these legal clearance requirements would be helpful in keeping this chart up to date, and your committee would appreciate receiving such information.

At the time of the last convention in March of 1967, your committee had 43 members and 3 Members Emeritus. During the past year we have lost 8 members. In my capacity as chairman, I wrote to the chief engineering officers of 25 U.S. and Canadian roads and apprized them that this committee had less than its authorized 70 members and that their road was not represented on it. We obtained 11 new members in the past year, 9 of these as a result of the letters I mentioned, and now have 46 members and 3 Members Emeritus, for a net gain of 3 members.

There may be a chief engineering officer present whose road is not represented on our committee or which is eligible for additional representation. Perhaps there is in your engineering department someone whom you would like to have become a member of Committee 28.

We are not interested in increasing the size of our committee merely for the sake of numerical count, but we are looking for new members who will take an active and constructive part in the work of our committee.

It is of interest to remember that the AREA rules permit a member to serve on two committees provided one or both committees are among those on a specified list, and that Committee 28 is on that list.

I want to thank all of the members of our committee for their service in the past year and also to recognize our committee officers.

As I call their name, I would like for each of them to stand for a moment.

Vice Chairman: M. E. Vosseller, senior draftsman, Central Railroad of New Jersey, Newark, N. J.

Secretary: R. L. Williams, office manager, Engineering Department, Illinois Central Railroad, Chicago.

Chairman Subcommittee 1: S. M. Dahl, assistant engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Chicago. Mr. Dahl is not with us at the moment.

Chairman, Subcommittee 2: R. D. Erhardt, assistant engineer, Gulf, Mobile & Ohio Railroad, Mobile, Ala. Mr. Erhardt was unable to attend the convention.

Chairman, Subcommittee 3: F. B. Persels, office engineer, Missouri Pacific Railroad, St. Louis, Mo.

Chairman, Subcommittee 4: G. P. Huhlein, assistant engineer, Louisville & Nashville Railroad, Louisville, Ky.

Chairman, Subcommittee 5: G. E. Henry, senior structural engineer, St. Louis–San Francisco Railway, Springfield, Mo.

Chairman, Subcommittee 6: J. E. Beran, chief draftsman, Chicago, Burlington & Quincy Railroad, Chicago.

Chairman, Subcommittee 7: C. H. Stephenson, assistant engineer, Louisville & Nashville Railroad, Knoxville, Tenn. Mr. Stephenson is not with us this morning. He is heading the subcommittee handling one of our two new subjects for the ensuing year.

I regret to advise that G. W. Honsa, structural engineer, Great Northern Railway, St. Paul, Minn., passed away suddenly on March 2. Mr. Honsa was the chairman of Subcommittee 8 which is handling the other one of our new subjects for the coming year. He was one of our new members, having joined Committee 28 last October.

Chairman Crawford: This completes the regular report of Committee 28, and it is with pleasure that we now present our special feature. We are honored in having four experts to participate in this special feature on Clearances and the Problems involved in Computerizing Them. It will begin with an illustrated address by Dr. H. N. Laden, director of research services*, C&O—B&O. At the conclusion of Dr. Laden's presentation, D. H. Shoemaker, chief engineer, Northern Pacific, D. E. Harmon, systems research officer, Southern, and R. H. Knittel, assistant engineer, Santa Fe, will each present brief remarks. Finally, these four gentlemen will answer questions from the audience, if any.

* Dr. Laden was promoted to assistant vice president—research, on April 1, 1968.

Computerization of High and Wide Clearances

By DR. H. N. LADEN

Assistant Vice President—Research
Chesapeake & Ohio Railway—Baltimore & Ohio Railroad

I. INTRODUCTION

A. Definition of the Clearance Problem

To ensure that the scope of discussion is clearly and unambiguously delimited, the clearance problem considered here is defined. A comprehensive treatment of the restrictions against movement of a vehicle or assembly of vehicles over the roadway would include, at least, consideration of heavy vehicle-lading combinations as well as what is commonly called high and wide clearances. However, so broad a treatment would be too much to include within the boundaries of this presentation.

Thus, the scope is limited to dimensional restrictions to movement. Weight distribution and axle-load restrictions are ignored, although dimensional and weight restrictions often tend to be associated. There is indeed an opportunity to be explored because of this association of integrating the computer system for clearing the route for a heavy load with that for clearing the route for a high and wide load. Here, only the high and wide clearance problem is considered. The questions we are faced with are:

1. Can a given shipment loaded on a given car in a prescribed way be routed from a given siding or loading point to another siding or unloading point by a prescribed route?
2. If not, where are the impediments to movement? What is the nature of them? How can the routing, equipment, loading, speed or train orders, or even the railroad property be arranged to accommodate the load?

B. Why is the Clearance Problem Important?

Considering all the difficulties associated with high and wide loads, one might ask why such unusual service is provided. Often, high-valued freight and a high tariff move is involved. There is considerable revenue at stake. There is rarely a question of the desirability of the traffic. Handled properly, the traffic can usually be very profitable. In fact, the concern is often the other way around—with the overly cautious Clearance Bureau which may impose excess restrictions, thereby turning away profitable loads. With more complete and reliable clearance data, the Clearance Bureaus would not normally be so conservative in their safety margins.

The moves involved are usually high-cost moves because of the special provisions often made to enable a movement. The size of expense calls for careful control and avoidance of unnecessary cost. These costs arise from:

1. furnishing special equipment for the load;
2. providing special loading and bracing, load inspection and measurement;
3. using circuitous routings to run around restrictions on normal service routes;
4. running specialized train operations including speed restrictions and delay of traffic on adjacent tracks;
5. shifting the load en route;

6. modifying equipment, such as spring sets, en route;
7. temporarily altering the railroad property, e.g., guard rails on bridges;
8. permanently altering the railroad such as single-tracking a double-track tunnel, daylighting a tunnel to accommodate TOFC and auto rack cars, and line changes to decrease curvature in horizontal alignment or vertical profile.

The least of the unusual costs may well be those for distributing orders to field personnel. With so much expense involved in handling high and wide loads, this aspect of railroading must be considered important.

It is so fundamental that the dimensional restrictions of railroads can seriously affect the shipper's product design and packaging and his commitments for deliveries to his customers.

The clearance problem is significant also for safety considerations. Personnel can carelessly expose themselves to the unusual projections of unanticipatedly high and wide loads. If a load is not properly cleared, damage may be done to lading, railroad equipment and structures. In consideration of the hazards, there is not much room for error. Yet, an excess of caution will cause profitable loads to be turned away.

C. Objectives

With better clearance procedures, we could:

1. improve accuracy and refine clearance limitations, thereby avoiding turning away loads or routing them circuitously, yet improve safety;
2. reduce the cost of operating Clearance Bureaus;
3. reduce car and train handling expense and car per diem;
4. provide faster response to shipper requests for routings and better service.

D. Why Is the Clearance Problem so Difficult?

1. The length of a railroad makes it difficult to have a complete and detailed inventory of all features of it between any two junctions or sidings which may be relevant to the clearance problem.

2. These features include tunnels, platforms, walls, other structures, fences, rock outcroppings and overhangs, guard rails, overpasses and supporting piers, vehicles and loads on adjacent tracks, and other features alongside and above the roadway.

3. There is at present a lack of reliable, accurate, economical, precise instrumentation for creating and updating a clearance file, i.e., a detailed register of the restrictive clearances between any two junctions or sidings of the property. Updating the inventory of clearance restrictions is essential because the railroad property is dynamic. Temporary and permanent changes take place which affect clearance. These include:

a. new structures, fences, sidings, etc. or modifications to old ones;
b. roadway deterioration—shifts in horizontal alignment, rock slides, growth of vegetation, ice and faults in tunnels, etc.;
c. roadway maintenance—reballasting in a tunnel, changes in superelevation, realignment, etc.

4. Other difficulties are introduced by the specialized and unfamiliar railroad equipment often used, the multi-car overhanging load and other unfamiliar loads and the specialized bracings.

5. Another difficulty is that of getting good and economical instrumentation in the field for precise measurements of equipment and load.

6. Then, there are the dynamics of cars, roadway, train and load underway. There are many unpredictables with which we may be confronted for each of these elements of the movement:

a. Car—wheel size variations and tire wear, hunting, truck skewing, lateral forces, roll, pitch, yaw, vertical vibration, torsion, longitudinal forces.

b. Roadway—roadway inputs to car dynamics from vertical and horizontal profile, gauge variations, subsoil and surface irregularities, track irregularities such as joints, etc.

c. Train dynamics, e.g., how a train will ride a vertical or horizontal curve—buff and slack action, lateral coupler forces, etc.

d. Load—shifting in transit.

7. The problem is complicated by being interline in nature. The originating carrier must determine the feasibility of the shipment clearing all roads on the route designated by the shipper or suggested by the origin road. This must be prior to dispatch of the load. To give the shipper a reasonably rapid reply to queries about feasibility of a routing, the cooperation of other roads in the routing is required. This is a problem whether or not the clearance system is computerized.

8. Finally, high and wide clearance is a critical operation with, at most, small margins for error.

II. RESPONSIBILITIES AND PROCEDURE FOR CLEARANCE OPERATIONS

In spite of all the difficulties, Clearance Bureaus function with reasonable success using familiar and traditional clearance procedures. But a brief review can remind us how many departments of the railroad have an interest in and get involved with clearances. Each such department is a potential customer for service by an integrated computer application covering all aspects of high and wide clearances.

A. Clearance Bureau—Center of Control

The Clearance Bureau is the center of control of clearances. In some railroads, this may be in the Transportation Department. In others, it may be in the Engineering Department. In the Bureau, authority for high and wide clearances is often combined with that for weight clearances. Now, we review subfunctions and information flow associated with dimensional clearances:

1. The shipper, traffic office, station agent, foreign line Clearance Bureau or other parties initiate a request for clearance data. Queries may come in from the field by mail, teletype, or telephone.

2. Local forces of the origin road are assigned to get the equipment and load detail from the shipment or to inspect the load and make measurements. This is usually a Mechanical Department responsibility.

3. The Bureau uses past experience for repetitive movements. Here is where a computer can help by saving a history of past moves, comparing the present request to past moves, and facilitating handling current requests on repetitive traffic. The only caution is that the Bureau better be aware of changes on the railroad or in shipment characteristics since the previous move of this kind.
4. For non-repetitive movements, the Bureau looks up condensed and, if necessary, detailed records of restrictions. It:

   a. defines the location and nature of obstacles;

   b. calculates geometrical clearance problems for the particular car and load such as on curves and in changes of vertical profile, using graphical and tabular aids as available;

   c. defines special restrictions needed to handle the move, restrictions involving equipment, loading, routing, train operations, etc.

Again, a computer containing a file of restrictions could be used to retrieve those restrictions which apply to the particular routing, compare load characteristics with dimensional tolerances, provide all the tabular storage and retrieval and geometric calculations

5. The Bureau constructs advice for relaying directions to the loading point, in transit points, destination, dispatchers, yard forces, and others involved in the physical aspects of the move as required.
6. Shipper, traffic office, freight agent and others may be advised of the movement plan.
7. In special cases, the Bureau polices the actual move, receiving reports of progress from the field, making and approving changes in a plan as necessary and keeping all interested parties informed.
8. The Bureau maintains a historical log of all clearance moves and makes it available to the L&D Section and the Legal Department in connection with claims.
9. Where there are temporary obstructions such as ice hanging in tunnels and from over passes, a special car may be ordered out to clear away the obstructions in advance of the move. For example, an icicle-cutting car is occasionally used in advance of auto rack cars. Fig. 1 is a picture of an icicle cutter used occasionally on C&O–B&O.
10. For interline routings, the Clearance Bureau of the origin road will check with the Clearance Bureaus of the other participating roads beyond the off junction for acceptability of a proposed routing.
11. Sometimes, a critical clearance situation exists in one spot or a few localized obstructions exist. Where restrictions are so isolated, the railroad may erect local detectors of extreme load extensions beyond critical points. These serve as on-the-spot checkers of clearance acceptability of the load to the oncoming obstruction. This extra safety measure can be of additional value in the event of accidental shifts of lading. Fig. 2 shows a device consisting of focused light beams and photoelectric detectors. An extreme load will break one or more beams and cause movement restrictions to be signalled to the train. Figs. 3 and 4 provide an expanded view of some detail of the device.

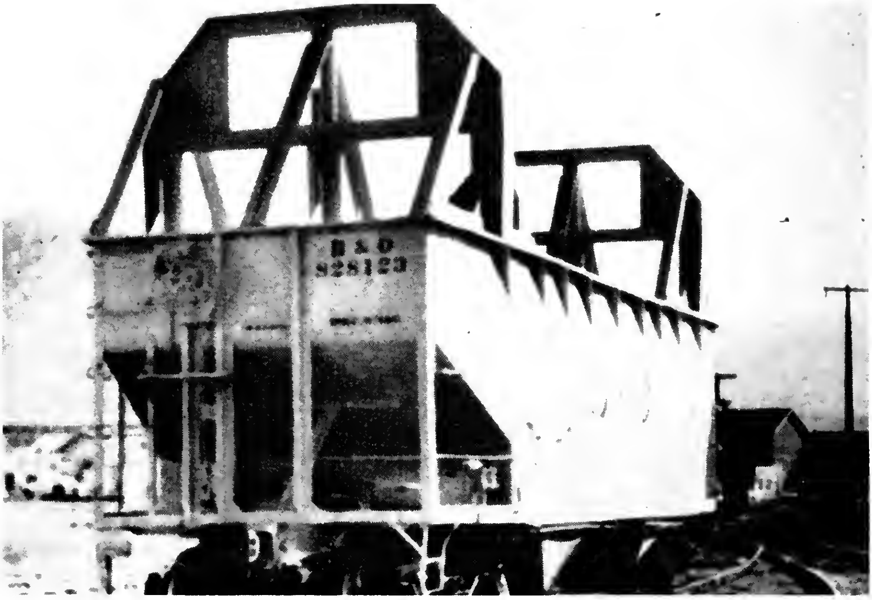


Fig. 1—Icicle cutting car.

12. The Clearance Bureau notes repeated hindrance from nuisance impediments and, together with the traffic Department, may initiate requests of the Engineering Department for permanent changes of right of way to remove obstructions.

So much for the general view of clearance operating. The Mechanical Department and the Engineering Department have *special* responsibilities in connection with high and wide loads and these are described next.

B. Special Mechanical Department Functions

The special Mechanical Department tasks are to provide for proper stowing of the load and then to describe both car and load in adequate dimensional detail. There is a great variety of shapes of loads. AREA Committee 28 has already developed suggestions for a standardized vocabulary and codes for describing various cars and loads.

In the chapter on clearances in the AREA Manual, there are described a number of fixed and mobile measuring devices for checking oversize loads before and during movement. The device shown in Fig. 2 is another example. Northern Pacific uses such a device at Laurel, Mont. to check westbound traffic prior to entry into a series of tunnels to ensure that high and wide loads will not hit the tunnel walls. The B&O has a similar device installed at Hyattsville, Md., designed to inspect TOFC loads prior to entry into Potomac Yard.

(Text continued on page 822)

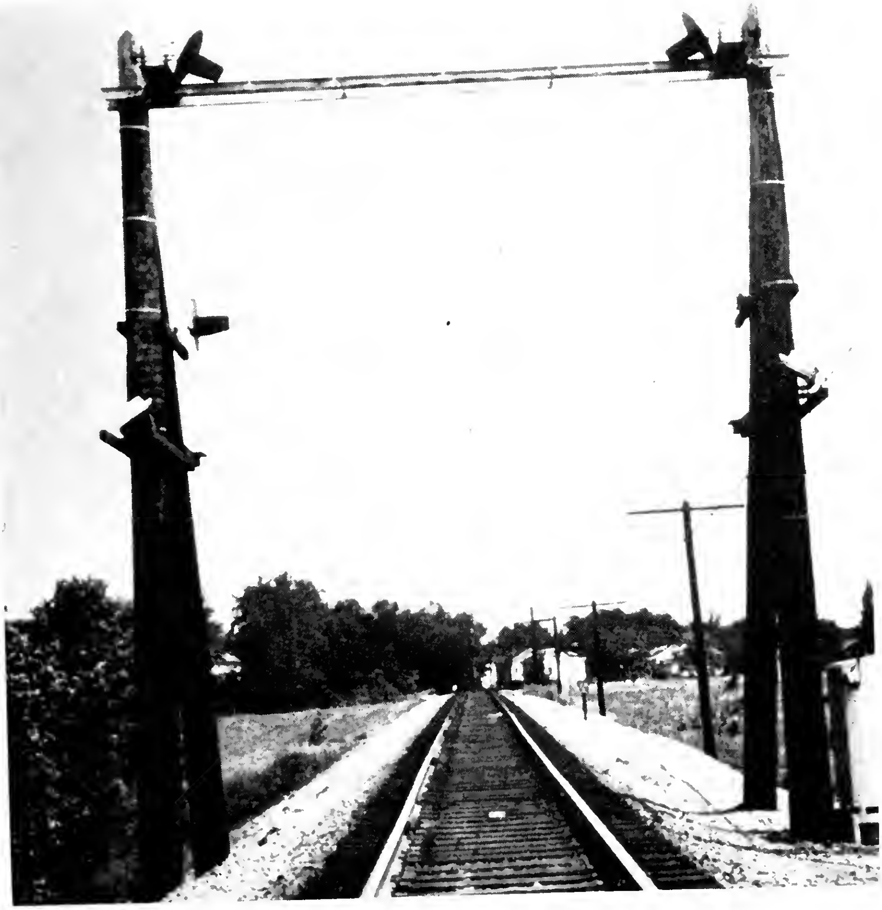


Fig. 2—Photoelectric device.

Fig. 3—Photoelectric detector of high and wide clearance.

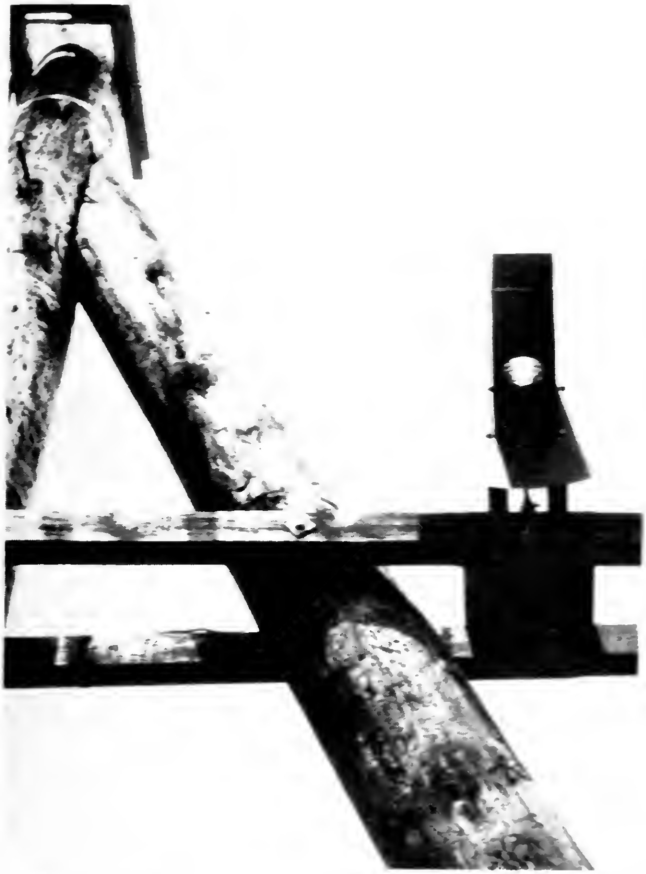


Fig. 4—Another view of photoelectric detector of high and wide clearance.

As for stowing of the load, bracing should not add to critical dimensions but must restrain against shifting in transit, which may create new clearance hazards. The effects of car springing and snubbing, yield in lading tiedowns, axle spacings, coupler lengths and restraints, and other factors affecting the ride of the car may need to be considered.

C. Special Engineering Department Functions

The special responsibilities of the Engineering Department with respect to clearance operations are of a most critical nature.

1. The primary one is the acquisition of clearance outlines of fixed track and roadway obstructions. This is not easy.

   a. Many outlines have been inherited from prior generations:

      (1) They are sometimes in the form of dried and faded charts with uncertain dimensional stability and scale factors.

      (2) Some have been measured and recorded with instruments of uncertain vintage and precision.

      (3) Current sets showing line changes are sometimes months and even years behind.

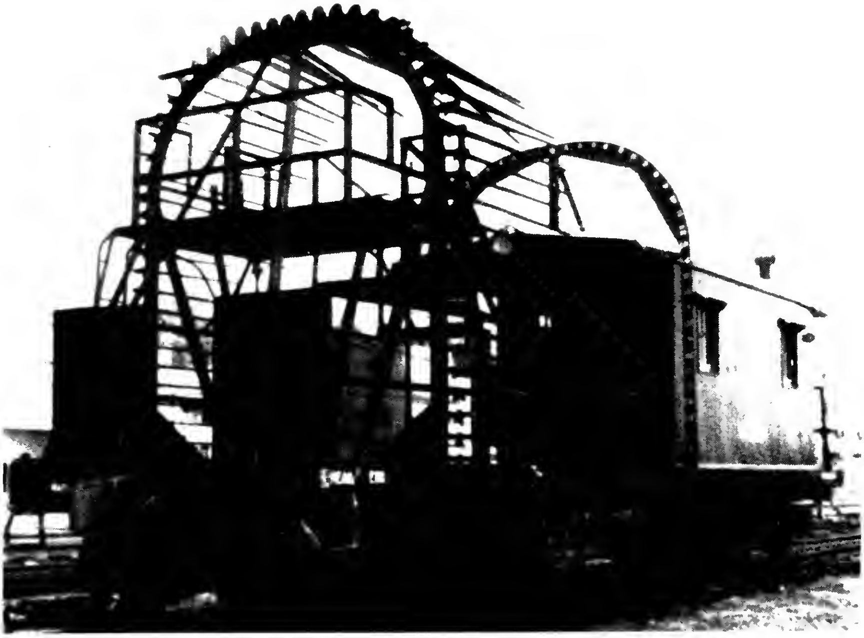
      (4) Further, without careful policing, the effects of roadway maintenance such as raising ballast or changing superelevation, may not be included.

   b. For measurement of obstructions, a number of tools are in use:

      (1) Feeler Car—Figs. 5, 6 and 7 show a feeler car. While this porcupine with adjustable quills hardly looks like a precision instrument, it can give dimensions to within ± ¼ inch. Unfortunately, manning the car requires a large work force. It is slow and expensive to operate and costly to maintain. The probes are moved and retracted by hand. Readings are manually recorded and side notes must be supplied and interpreted. Skilled Engineering personnel are required for this and for drawing critical contours to scale, adding clarifying notes, and organizing tabular values related to the outlines.

      (2) One way to reduce these costs is to use a semi-automatic, high-rail car instrumented to acquire clearance outline data photographically. Figs. 8, 9, 10 and 11 show instrumentation mounted on a converted station wagon for obtaining clearance outlines. Only two men are required to operate this car and obtain the necessary notes and measurements. More important, the information about clearances is on film in such a way that it can be translated for automatic processing by computer without extra personnel costs.

Figs. 8 to 11 show the SCOPE car fully rigged for measurement. It is a 1965 Plymouth station wagon equipped with a Hy-Rail adapter. The car is instrumented with optics which produce a thin sheet of light perpendicular to the track. Mounted off the front bumper is the light source assembly, which consists of a spherical reflecting mirror, a mercury arc lamp rated at about 130 million candles per square foot, and a rotating mirror system mounted about 3 ft above top of rail.



Figs. 5 and 6—Two views of feeler car for obtaining clearance contours.

Fig. 7—Another view of feeler car for obtaining clearance contours.

The spherical mirror is mounted behind the lamp and directs a controlled beam to a rotating device containing two plane mirrors each oriented at 45° to the driving axis, registered on the center line of track. The plane mirrors split the beam in two, 180° apart. The rotation of the mirrors produces a fine beam about 2 inches wide scanning in a disk perpendicular to track and roadway.

The tripod and camera assembly can be seen on top of the wagon. The camera records, on 35-mm film, the intersection of the light plane and fixed obstructions from top of rail to 22 ft above top of rail and for a width of 9 ft each side of the track center line. The present design of this car system requires operation at night for satisfactory film records.

In the manual interpretation of data on obstruction contours, the exposed negative must be mounted on a calibrated grid scale in a special film reader. Alignment marks on the film and on the scale facilitate proper registration. Accuracies to within ± ½ inch are attainable. Automation of this film reading is one aspect of the computerization herein discussed.

The camera is undergoing development to make it more automatic. Facilities will be added for automatic changes in shutter openings, as well as for frame identification and filtering. Adaptation to daylight operation by use of laser beam is being investigated. This will enable the car to be used on a 3-shift per day basis rather than only at night. Simplifying interpretation of the photographs and automatic conversion of the contours to magnetic tape for computer processing are other important developments. These are discussed further.

2. Data Reduction Automation—The SCOPE car permits rapid, economical updating of clearance outline information. Once up-to-date clearance photography

(Text continued on page 828)

Fig. 8—SCOPE car.

Fig. 9—Rear view of SCOPE car.

Figs. 10 and 11—Other views of SCOPE car.

has been obtained, its information can be added to a master file of fixed obstructions. However, one need not wait for SCOPE. A start for the master file can be made from scale drawings of clearance outlines available on most railroads.

Now, these clearance outlines, whether on film or scaled drawings, are analog data, not discrete numerical data. These analogs can be converted into numerical coordinates by a special device called an analog-to-digital converter. We call this digitizing. This is done by first establishing a reference point, say top of rail on the center line of track, as represented on film or drawing and a scale factor. The computer operator then places the point of an electric stylus on a point of the contour to be digitized and presses a button. The X and Y displacements of the stylus are converted into two d-c voltages which are converted by digital voltmeters into two digital values which are the coordinates respectively of the stylus point, using the selected reference point as the origin. These two numerical values then actuate digit by digit the appropriate column and row punch of a punched card keypunch, so that the X and Y values fall in assigned columns. The keypunch operator places the stylus on a further point of the contour to be digitized and repeats the operation.

All of this is fairly rapid. Several hundred points on contours can be digitized per hour. Scale drawings can be used as is, while films are first enlarged and then projected on to a ground glass screen for operator viewing and plotting.

In other industries, automatic curve followers of a photoelectric nature have been used further to automate the digitization. The curve follower generates (X, Y) analog voltages which go into the analog-to-digital conversion as in manual curve tracing. The only change is that of a stylus to follow the contour and to do so automatically.

Next follows perhaps the most critical operation in any computerization—verification of the input data. This is done on another specialized device, a digital-to-analog converter. In this machine, the numbers on the punch cards, produced in the previous operation, are converted back into X & Y voltages which drive motors displacing the pen of a curve plotter in the X & Y direction. Contours can be plotted to any practical scale desired. The machine-plotted contours, on a scale consistent with the originals, are superimposed over the original contours. If these match within a reasonable tolerance, then the input is considered verified.

There are many advantages in the procedure just described. In addition to producing scaled drawings from films automatically, one can produce tabular values corresponding to the contours for further use by railway personnel.

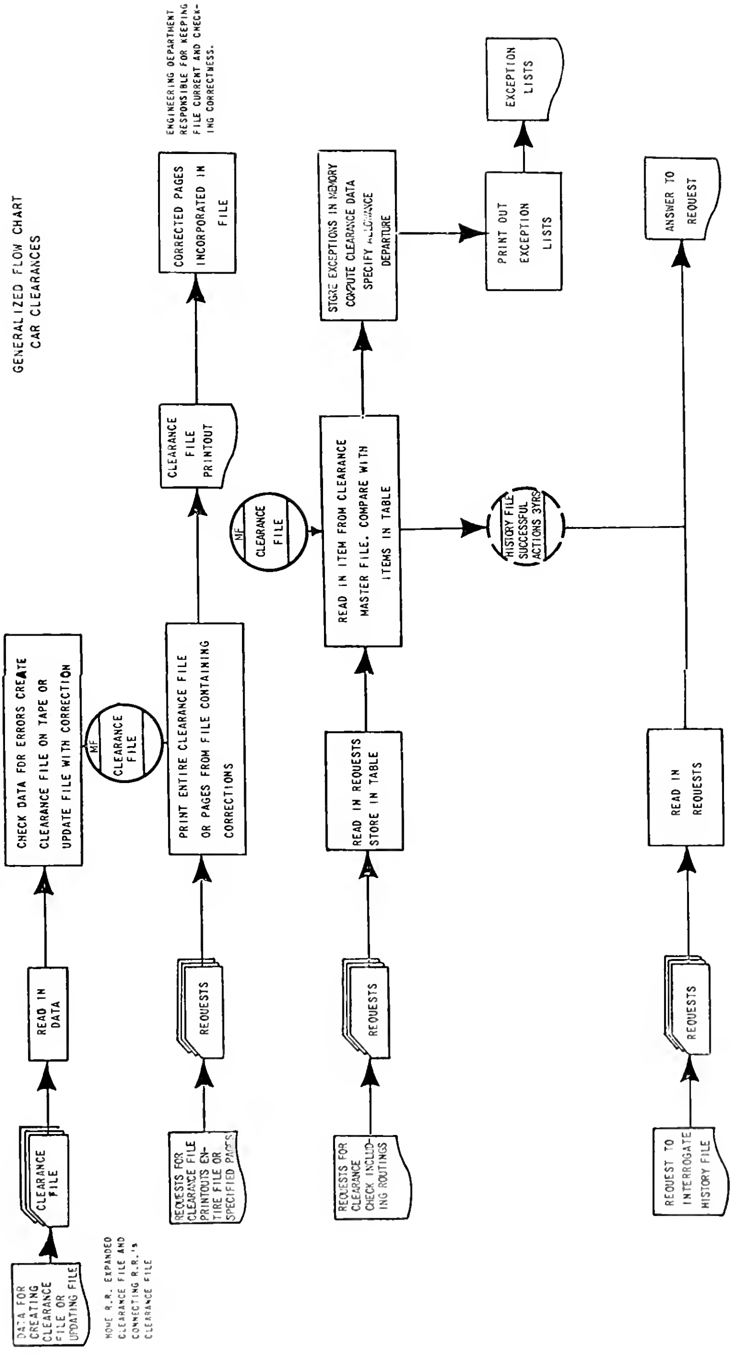
IV. COMPUTERIZATION

We can put together economical, automatic techniques for obtaining contours of restricted sections in digital form to visualize a clearance system that can be highly automated with the aid of a digital computer. Fig. 12 is a highly generalized flow chart of such a computer system design.

There are three basic phases in the system depicted on this flow chart. These are:

1. master file preparation, update and print out;
2. the clearance function; and
3. the historical summary.

FIGURE 12
GENERALIZED FLOW CHART
CAR CLEARANCES



In the upper two lines of the chart is the master file phase in which the digitized descriptions of fixed track and roadway obstruction outlines are converted into allowable horizontal measurements for all heights above the top of rail at 3-inch intervals. A file is constructed and maintained which can be used for clearance computation or printing and review.

The clearance function phase utilizes the master file in conjunction with a load and route description. A table is formed describing the horizontal dimensions of the load at various increments of height above top of rail. Items are read in from the clearance master file and compared with the load description table to determine if the load will clear. If not, an exception list is printed which gives the details of failure to clear. A series of alternative routes is stored in order of preference which can be examined in turn until a route is found that will not only clear but be acceptable to the Traffic Department.

The history phase uses a file of prior clearance actions over the past two to three years. As was seen in the preceding phase, this history file is updated through the Clearance function. It is available for interrogation concerning loads and routes already cleared as well as locations exhibiting excessive hindrance to operations. If a previous clearance case is sufficiently similar to the current request, the History file may be used directly. One purpose of this file is to record the frequency of occurrence of clearance problems by location. Analysis of this file can provide the basis for potential line relocations or structure modifications.

There are many other aspects of the computer system that merit mention. A few words about input preparation: The various shapes of loads on open top cars can be summarized into several standard geometric forms and codes. These should contain a minimum of dimensions describing the shape of the load. Needless to say, accuracy is important in the measuring devices used for checking oversize loads.

For output, the computer can be used to considerable advantage particularly if it has communications capabilities. The results of computer processing of a request for high-and wide clearance can be summarized in an acceptable message format and transmitted automatically by teletype to dispatchers and superintendents of the divisions concerned. Monitoring and preliminary authorization of these outputs by Transportation Clearance Bureau is assumed.

As for the intermediate processing, the computer surely facilitates Clearance computations, using accepted procedures. It is no longer necessary to make conservative assumptions and estimates. Quick computations can be made as exact as is known for mid-offsets and end overhangs whether on tangent or curved track, for multiple as well as single cars and so as to include effects of springing or car rocking. Overly conservative safety margins can be reduced and more business accepted.

The computer application described in such a coarse way is very complex and requires extensive documentation and programming. It is hoped that there will be a joint effort in AREA, together with the AAR Data Systems Division, to develop standards for computerization and automatic processing of clearance requests. This could then lead to sharing the burden of the detailed computer systems analysis and programming. I hope that all railroads will contribute to this effort to insure economy in preparation and the best in performance.

(Applause)

Computerized Clearances on the Northern Pacific Railway

By D. H. SHOEMAKER

Chief Engineer, Northern Pacific Railway

I am only going to say a few things. First, the plan and program that Dr. Laden has suggested to put computerized clearances on a national basis is fine, but I am not sure just how to go about it. When an individual railroad starts thinking about putting these data on a computer, the first thing you have to do is to keep it simple.

I think the Northern Pacific was the first railroad that put clearances on a computer. We didn't try to put all of them on at once. We didn't include multiple loads, or the heavy loads.

My advice to you chief engineers and others in this room who are considering putting your clearances on computers is to keep the original input in the engineering department. You will find when you start computerizing your clearances, as we have, and it is working very nicely on our road, that the transportation department will want to get in on it.

You may have different kinds of Clearance Bureaus. The Clearance Bureau could be one or two men in the engineering department or a group of clerical people in the transportation department. But unless you keep the clearance data within the engineering department, among the people who know what constitutes a restrictive clearance and how to correct it, you have lost a lot of control.

We also put in the first automatic photocell electrical measuring device. It has been in operation four years or longer, but it still doesn't work right. We are getting some information out of it, but we have had trouble with it and I don't know if we will ever get it to work. It is a good check on the clearances we work out manually for all our westbound trains.

We have a lot of tunnels on the NP, and we have a lot of clearance problems. We have to reject 25 or 30 cars for clearance reasons every day. The clearance program we developed has been a great help to people trying to find out whether they can move their load on our railroad.

We kept the program simple but I think that still we saved probably the full time of one man (and he was one of our better men in our drafting room) by putting it in. It is excellent.

A number of roads have sent people to our railroad to see what we have done. Our program isn't as sophisticated as the one Dr. Laden outlined. It doesn't necessarily have to be that sophisticated. But now that Dr. Laden has suggested that there be a joint effort with the AAR to develop standards for computerization and automatic processing of clearance requests, it might be that our little old simplified device is not sophisticated enough. But it works and gives us accurate information, much more accurate than we can get by hand.

(Applause)

Basic Points to Be Considered in Computerizing the Clearance of Oversize Loads

By D. E. HARMON

Systems Research Officer, Southern Railway System

We have heard a discussion of many of the problems to be considered in computerizing the clearance of oversize loads. I would like at this time to stress only two basic points:

1. The system should have the ability to answer the most difficult clearance problem.
2. The clearance data for the system must be complete, accurate and up to date.

Let us look at point 1—the system should have the ability to answer the most difficult clearance problem. Computers, while rapid in operation, are expensive on a per hour basis and more expensive on small jobs than on big ones. The programming of a clearance system, while largely a one-time cost, is not inexpensive and must include maintenance of all necessary data files.

The preparation of computer input is tedious and maintenance of data files takes time and effort. Where *is* the real profit in computers? It is in handling either large masses of data or in doing intricate calculations with extreme rapidity and accuracy. The major profit from computerizing clearance is in the handling of the most intricate problem. The simple problem can be done more quickly and inexpensively by an experienced man. The computer excels on the complex problem. When you get the answer in minutes to the problem that would have taken a week or more is when you're glad you have a computer system.

Now let us look at point 2—the clearance data for the system must be complete, accurate and up to date. By complete data let us assume we also mean a data system which will not become outmoded in a few years.

It makes little sense to develop an intricate computer system if the only answer you can expect to the difficult problem is, "insufficient data are available, go make another field survey." It makes little more sense to make exacting calculations on data whose accuracy is dubious whether due to manner of measurement or due to age. Most of you know that clearances do change in time, regardless of instructions or procedures, requiring periodic remeasurement. One should also be aware of the human tendency to accept the computer result as exact, while in fact it can be no better than the data available.

Let me repeat: 1) the system should have the ability to answer the most difficult clearance problem; 2) the clearance data for the system must be complete, accurate and up to date, and this is purely for safety.

(Applause)

Santa Fe's High–Wide Problem Computerized

By R. H. KNITTEL

Assistant Engineer, Atchison, Topeka & Santa Fe Railway

Gentlemen: Computers are playing a major role in our lives today. I am reminded of a recent talk by our chief engineer system, R. H. Beeder, who said, in his closing remarks:

"When one reflects on the number of uses of data processing one cannot help but recall the observations of our friend from Colorado. He said, 'The human brain is a perfectly splendid computer and of course the first one, with several billion circuits. It can operate for hours on the calories contained in one-half a potato chip. It is mobile, occupies less than a cubic foot of space, and is produced entirely by unskilled labor.' "

Although not a matter of record in the archives of the Santa Fe, it is conceivable that the problems associated with the handling of high-wide loads started with a construction train moving to the first rail head.

History vividly points up that our industry has thrived upon new technology, but today's observations disclose that growth of the complexity of moving high-wide loads over the railway systems has more than kept pace with the industry's development and it has become an ever greater and more challenging problem. It is greater, not only in terms of the physical size of loads and equipment handled, but also because of its more frequent recurrence.

Technology, as in the past, has provided a tool—the electronic computer—which may be used to greatly reduce the magnitude of the problem. Santa Fe now proposes to make use of that tool by implementing its clearance program, which is designed to provide fast, uniform and accurate determination of movement of high-wide loads across a railway system or any portion thereof.

The program is designed to seek alternate route selections which are given priority indicated by the order in which they are listed. These routes, the limits of which are dictated by either physical or operating features, and the obstructions within these limits are retained on a master file. Loads of any configuration, concentric or non-concentric, can be handled and may be either single loads or bolstered loads carried on multiple cars.

The load is divided into 3-inch increments of height for accurate analysis. However, it is necessary only to detail the breaks in the load configuration, as the program will interpolate for the intermediate increments.

The program provides for movement simulation of the load under real operating conditions by considering lateral displacement to be comprised of the effects of speed, length of spring, height of center of gravity, bolster wear, and track gage anomalies. The numerical values given these components were derived from statistics published by AAR and AREA committees in their Report No. ER-82, dated January 1963 and Volume 59 dated 1958, respectively.

Testing may be done in any of the following MODES:

1. At unrestricted speed, where possible, but as restricted speed (4 mph) where necessary.
2. At unrestricted speed only.
3. Non-concentric loads, carried on two cars, may be run headed in one direction and, on completing the run, the load direction will be reversed by the program and run again.

Performing in the above MODES, the program will seek routes from origin to destination through as many as five lists of selections.

In the following MODES the program will not deviate from the selections but will go through them exactly as they are listed:

1. Loads may be forced over one entire selection only to provide, at each unpassable obstruction, a detailed list of impairments as they may occur at all levels. This feature will be used when it has been found that a load must be rejected unless certain load alterations may be made.
2. Loads may be forced over as many as five entire selections so as to develop a list of unpassable obstructions. This feature will be most useful in TCS territories where it is desirable to make the most use of non-directional traffic.

In general, the logic utilized by the program is the same as would be used in hand calculations. The basic criteria behind this logic are:

A. Roll (oscillation) is considered to be maximum toward the obstruction.

B. Rail and car wear are at maximum and will result in a reduction of clearance.

C. When meeting another car or load, either on curved or tangent track, all forces involved are acting so as to reduce the clearance between the loads.

D. The program does not calculate vertical oscillation. However, it does provide for this by adjusting the dimensions of the load in such a manner that each increment is raised and lowered 3 inches during the calculation. This not only covers the vertical movement, but also compensates for minor errors in field measurement. Each load increment, at 3-inch intervals of height, is compared with a corresponding increment of the obstruction.

E. After all factors have been taken into consideration, the load must have a side clearance of greater than 1 inch to be considered as clear.

As indicated in Item C above, in addition to the load being tested against normal obstructions, that is, bridges, etc., it is also tested against the silhouettes of three opposing configurations, both on tangent track with 14-ft centers and on curves. The tangent check is instigated by the program for all loads. However, the comparison on curves is done only if the curve appears as an obstruction on the master file. The three silhouettes are representative of a large freight car, a passenger car (dome car), and a PLC (published line clearance) load.

The results of fouling a normal obstruction will be dependent upon the mode in which the load is being tested. For instance, a load in the "unrestricted" mode which fouls will result in the rejection of the route and another selection being introduced; but in the "restricted" modes, the load would be reduced in speed so as to reduce spring action and lateral displacement to simulate static conditions and it will then be tested again against the same obstruction. If the load will clear under these conditions, a message will be written stating the location and that the speed must be restricted to 4 mph, and then the program will proceed to the next obstruction. On the other hand, if it fouls at 4 mph, the result is rejection of the route and a new selection is then tested.

Finally, the printed output will contain the reproduction of the load configuration, routing, car identification, direction of movement, and precise messages stating: 1) the location, by number and route, at each point where a load is to be restricted in speed, 2) the location at points where the load fouls and is to be rejected, 3) alternate routing, and 4) a summary message advising how the load may be handled or a message rejecting the load. (Applause)

CHAIRMAN CRAWFORD: On behalf of Committee 28 I want to thank Dr. Laden, Mr. Shoemaker, Mr. Harmon and Mr. Knittle for a most interesting and timely special feature.

Mr. Vice President, this concludes the report and special feature of Committee 28—Clearances, at the 1968 Convention of the AREA.

VICE PRESIDENT WILSON: Thank you for your report, Mr. Crawford, and for your efforts to stimulate membership on Committee 28. I assure you that your efforts have the support of the Board of Direction. That most interesting and timely panel discussion is certainly indicative of the important work you and the members of your committee are doing in the clearance area.

To Dr. Laden and the other members of the panel, I want to say "well done" and express to them the appreciation of the Association for their efforts on its behalf. You have added to the knowledge of everyone here and given us a lot to think about.

Discussion on Iron and Steel Structures

(For report, see Bulletin 611, pages 453–504)

VICE PRESIDENT WILSON: We will now hear from one of our elite committees, a committee whose Manual chapter probably is used more than any other single chapter and has stature in many parts of the world. I refer, of course, to Committee 15—Iron and Steel Structures, which along with Committee 30—Impact and Bridge Stresses, has developed the widely heralded "Specifications for Fixed and Movable Steel Railway Bridges."

The chairman of this committee is D. L. Nord, engineer of design, Illinois Central Railroad, Chicago. Mr. Nord, you may proceed as soon as the members of your committee are in place on the platform.

CHAIRMAN D. L. NORD: Mr. Vice President, members and guests:

The annual report of Committee 15 is published in Bulletin 611, pages 453 to 504, incl. The Manual recommendations of Committee 15, as published in the Supplement to Bulletin 610, pages 371 to 373, incl., have been approved by the Board of Direction for adoption and publication in the Manual. No oral reports will be made at this time except a report on Assignment 1 (a)—Complete Revision of Chapter 15 of the Manual, which will be presented by the chairman of the subcommittee, G. W. Salmon, engineer of bridges, Seaboard Coast Line Railroad. Mr. Salmon.

Assignment 1 (a)—Complete Revision of Chapter 15 of the Manual

G. W. SALMON: Committee 15 realized several years ago that its specifications were in need of a complete revision. The last overall revision was in 1935–1936, some 32 years ago. In the interim, much research data have become available, and many new developments have occurred. While the specifications have been revised piecemeal over the years, we have not been able to keep up.

In June 1963, a subcommittee was appointed to study revision procedures. This subcommittee reported in April 1964 with recommendations. At this time the specifications were divided into sections and a subcommittee was appointed to rewrite each section. Some progress was made during 1964 and early 1965, but we were beginning to realize the work required more time than any of us were able to spare, and that the work of each subcommittee had to be continuously coordinated with each of the others. After much discussion, the committee reached the conclusion that without an individual who could devote the necessary time to put the various articles, new and old, into a coordinated arrangement, we had little hope of ever completing the rewrite work.

We asked for help from the AAR, and with its cooperation we persuaded W. H. Jameson, who had recently retired as chief engineer of Bethlehem Steel Corporation to take on the job of coordinator. We knew him well as a former member of our committee, and he brought to us many years of experience in the design, fabrication and erection of steel bridges. In addition, he had a major part in rewriting the present AISC Manual and the AWS Specifications.

All of this took time, and it was February 1967 before we really began to make progress. In the meantime, we had abolished the several subcommittee handling the various sections and had established a ten-man subcommittee to work with Mr. Jameson. This subcommittee consists of five men from railroads, two from consulting firms, two from the steel industry, and one university professor. We believe this gives us the best possible coverage in the railroad bridge field.

In the past year, excellent progress has been made, although the job has turned out to be more complicated and time consuming than any of us had anticipated.

You will find Part 1—Design, and Part 2—Fabrication, in Bulletin 611. While these two parts are published as information, they have, except for four articles, been approved by letter ballot for adoption in the Manual. There are, as might be expected, some editorial corrections to be made, but essentially Parts 1 and 2 will remain as now published.

Many articles have been deleted, many rewritten and many new articles added. Specifications covering welded bridges have been included, and the specifications have been revised to take into account the available research data. The various articles have been rearranged in a more logical sequence, and numbered in accordance with the Dewey decimal system. As most railroad bridges are of ASTM A 36 steel, Parts 1 and 2 have been written for that specific material, or its equivalent. It is suggested that you review this material, and your comments will be most welcome.

The remaining parts will be as follows:

Part 3—High-Strength Steels

This will cover those steels considered suitable for use in railroad bridges where yield points higher than A 36 are required or can be justified. Considerable work remains to be done, but this part is rapidly taking shape.

Part 4—Erection

This part is completed, and is presently out for letter ballot.

Part 5—Special Types of Construction

This will cover composite steel and concrete, continuous bridges and rigid frames, and is practically completed.

Part 6—Movable Bridges

This was completely revised in 1953 and, except for renumbering and minor changes, will remain as is.

Part 7—Maintenance and Rating

Considerable work remains, consisting mostly of editing and rearrangement.

Part 8—Miscellaneous

This will contain specifications for turntables and other items not covered by Parts 1 through 7. We have not yet started on this part.

In addition a bibliography and explanation of various articles will be included. This work is now underway by the Subcommittee on Bibliography, Committee Assignment 7.

We feel that we are well along with a completely revised specification, modern and up to date in every respect. We expect to complete the revisions this year, and our goal is to submit the revised specifications for adoption by the AREA in 1969.

At this time, I would like to express my appreciation and thanks to Mr. Jameson, the members of the subcommittee, the committee members, and the AAR for their cooperation, counsel and hard work. Without all of them, we would still be where we were in 1963.

Mr. Chairman, this concludes the report on Assignment 1 (a).

Chairman Nord: Mr. Vice President, this concludes the report of Committee 15.

(Applause)

Vice President Wilson: Thank you, Mr. Nord, and Mr. Salmon, for your report on the status of the major revision to Chapter 15 of the Manual. The efforts of yourselves and your committee are greatly appreciated.

Your committee is excused with the thanks of the Association.

Discussion on Wood Bridges and Trestles

(For report, see Bulletin 611, pages 389–401)

Vice President Wilson: The second of our technical committees to report at this session will be Committee 7—Wood Bridges and Trestles, the chairman of which is D. V. Sartore, chief engineer, Burlington Lines, Chicago.

Mr. Sartore, you may proceed as soon as all members of your committee are in place.

Chairman D. V. Sartore: Mr. Vice President, members and guests:

The complete report of Committee 7 is contained in the January 1968 issue of the Bulletin, No. 611, pages 389 through 401.

I would like to call your particular attention to page 390, which contains a memoir in honor of Herbert M. Church, a former chairman of Committee 7, who passed away late in 1966.

Before getting on with the subcommittee reports, I would like to mention that Kenneth L. DeBlois, formerly of the New York Central Railroad and presently with Westenhoff and Novick, Consulting Engineers, has recently been elected Member Emeritus of Committee 7.

Assignment 1—Revision of Manual

Chairman Sartore: No report will be made on Assignment 1. Work is being progressed under Subcommittee Chairman James Budzileni, assistant to engineer of bridges, Rock Island Railroad. Mr. Budzileni, will you please stand and be recognized.

Assignment 2—Grading Rules and Classification of Lumber for Railway Uses; Specifications for Structural Timber

Chairman Sartore: No report will be made on Assignment 2. Work is being progressed under Subcommittee Chairman John Ridgeway, engineer structures—processes, Bessemer & Lake Erie Railroad. Mr. Ridgeway is not here today.

Assignment 3—Specifications for Design of Wood Bridges and Trestles

Chairman Sartore: No report will be made on Assignment 3. Work is being progressed under Subcommittee Chairman James Helm, assistant engineer, Illinois Central Railroad. Mr. Helm, will you please stand and be recognized.

Assignment 4—Methods of Fireproofing Wood Bridges and Trestle, Including Fire-Retardant Paints

Chairman Sartore: No report will be made on Assignment 4. Work is being progressed under Subcommittee Chairman George Sells, general foreman bridges and buildings and water service, Santa Fe Railway. Mr. Sells, will you please stand and be recognized.

Assignment 5—Design of Structural Glued Laminated Wood Bridges and Trestles

Chairman Sartore: Subcommittee Chairman James Gustafson, assistant bridge engineer, Northern Pacific Railway, was unable to be here today, so I will read his report.

Your committee has submitted a revision to that section of the Manual that deals with the Design of Glued, Laminated Members. The revised material appears on pages 362–366 of Bulletin 610.

For the present, we will maintain the existing tables, with the objective of updating them in the near future. The tables are out of date in regard to the lumber grades being used in the various laminations. Currently some of the industry grading rules are being rewritten, and future tables should relate to any changes in these grade designations.

Committee 7 is currently testing glued, laminated members and solid-sawn members in sizes normally used in trestle design. These results should be reflected in the allowable stresses shown in our new tables.

The primary objective in providing the rewritten specification at this time is to incorporate U.S. Commercial Standard CS 253–63 into our specification. By purchasing a product certified under this Standard, a member of the grade required should be delivered without the necessity of continual inspection. This recognizes the fact that the techniques used to produce a member may be as important as the material used. Any failure in a joint would be as serious as a failure in the lumber. Reducing the cost of inspection may be as important as reducing costs in the material itself.

Assignment 6—Evaluation of Cost of Various Sizes of Bridge Timbers

CHAIRMAN SARTORE: This is a new subject under Subcommittee Chairman Larry Kubacki, engineer bridges and buildings, Penn Central Company. There is no report to present at this time. Mr. Kubacki was unable to be here today.

Assignment 7—Repeated Loading of Timber Structures

CHAIRMAN SARTORE: Report on Assignment 7 will be presented by Subcommittee Chairman Clarence Lund, assistant chief engineer—structures, Milwaukee road. Mr. Lund.

C. V. LUND: Mr. President, Mr. Chairman, members and guests:

Your committee presents this year a synopsis of the fourth series of tests on full-size timber stringers in static and repeated loading, with particular respect to shear strength. The complete report is printed as Research Center Report No. ER-76.

Solid sawn treated Southern pine stringers, obtained from the stocks of a member road, were used in these tests. The shear strength was found to approximate 215 psi at 2,000,000 cycles of stress, as compared to a working stress currently allowed in design of 125 psi for this grade of timber, based however on long duration of static loading.

The investigation again uncovered the failure of a railroad to actually procure the quality of solid sawn stringers specified by its Engineering Department. It would appear that there exists an indifference to specifications in the purchase of timber. Allowable stresses as well as serviceability depend on quality as reflected in the grading rules, and it is urged that each railroad inquire into the practices followed in the supplying of timber and conformity to specifications.

The results of these tests, together with that of other investigations, is considered sufficient to now permit a preliminary review of currently allowable working stresses in shear, and this will be progressed by your committee in the coming year.

The AAR Research Center is presently obtaining material for a series of tests of glued laminated stringers specifically designed to reflect both the effects of slope of grain and the loss of strength due to preservative treatment in verification of the adjustments made for these factors in the determination of working stresses. This should be a most informative investigation, the results of which should be available for reporting next year.

Assignment 8—Protection of Pile Cut-Offs; Protection of Piling Against Marine Organisms by Means Other Than by Preservatives

CHAIRMAN SARTORE: Report on Assignment 8 will be presented by Subcommittee Chairman William Thompson, division engineer, Chicago, Burlington & Quincy. Mr. Thompson is also the vice chairman of Committee 7.

W. A. THOMPSON: Mr. Chairman, members and guests:

Your committee published a progress report in Bulletin 611, January 1968, to familiarize the members with the information presently available concerning protection of pile cut-offs, and protection of piling against marine organisms, by means other than by preservatives. While there is considerable work being done on these subjects by various groups at the present time, it does not appear that any additional pertinent information will be available in the near future. Therefore, this report is submitted as a progress report with the recommendation that the subject be discontinued until there are further developments.

Assignment 9—Study of In-Place Preservative Treatment of Timber Trestles

Chairman Sartore: A progress report on Assignment 9 appears on page 400 of Bulletin 611, and no further report will be presented today. D. L. Walker engineer—structures, Frisco Railway, is subcommittee chairman. Mr. Walker could not be with us today.

Assignment 10—Non-Destructive Testing of Wood

Chairman Sartore: Report on Assignment 10 will be presented by subcommittee Chairman Floyd Schneider, Assistant Engineer, Santa Fe Railway. Mr. Schneider.

F. E. Schneider: Mr. Vice President, Mr. Chairman, members and guests:

The AAR recently published a report, No. ER-75, on the demonstration of two sonic pole testing devices at the AAR Laboratory, measuring and recording known decay in some old bridge timbers.

After the demonstrations were completed, the timbers were cut apart to compare the instrument readings with the actual internal condition of the timber. The report shows that both devices were able to indicate that decay was present. Neither instrument indicated the size of any internal void, but the manufacturers made no claim that they would. Moisture in the wood or on the surface did not have any effect on the instrument readings.

One of the instruments will be loaned to the AAR for further testing. We plan to check the reliability of this instrument in the field on several old timber bridges on which we have complete condition reports from previous borings and inspections.

We would appreciate information on any other instruments or devices on the market for determining the internal condition of timber so they can be investigated.

Chairman Sartore: This concludes the report on our assignments.

Your committee is happy to present at this time as a special feature, an illustrated talk entitled, "The Future of Timber in Railroad Bridges," by Maurice J. Rhude, director of timber engineering, Koppers Company, Inc., Forest Products Division, Unit Structures Department.

Mr. Rhude received his B.S. and M.S. degrees in civil engineering from the University of Wisconsin, and later served as an instructor in the University's civil engineering department.

He served as an engineer at the U. S. Forest Products Laboratory just prior to joining Unit Structures, Inc., in 1951, where he held the positions of chief engineer and vice president.

Mr. Rhude is a registered professional engineer. He is past chairman of the Wood Engineering Division of the Forest Products Research Society, and is currently chairman of the following committees: (1) ASCE Task Committee on Wood Research, (2) AITC Research Committee, and (3) Special Task Committee of Subcommittee II on Laminated Timber Stresses of ASTM Committee D7 on Wood.

He is a native of Wisconsin, and he resides in Marinette, Wis., with his wife and six sons.

His educational background and later research and business activities in the forest products field afford an ideal background for the qualifications needed to present this special feature to you today. Mr. Rhude.

The Future of Timber in Railroad Bridges

By MAURICE J. RHUDE

Director of Timber Engineering, Koppers Company, Inc., Unit Structures Department

BACKGROUND

In 1901, the President of the American Railway Engineering and Maintenance Association said:

"We cannot go in indefinitely renewing bridges in wood. Timber is becoming scarcer and more expensive year by year."

In 1902, the Committee on Wood Bridges and Trestles wrote:

"The day is past and gone when a wooden bridge can be considered a desirable structure on a railroad. In putting them in we do so with almost an assurance that they will be replaced by a permanent structure within the life of the first timber used in the structure."

This is a poor foundation upon which to build a presentation on "The Future of Timber in Railroad Bridges"! I am reminded of a set of stanzas in "Catholic Tales" by Dorothy Sayers:

"I made the wonderful carven beams
Of Cedar and of Oak
To build King Solomon's house of dreams
With many a hammer-stroke,
And the gilded, wide-winged cherubims.

"I have no thought in my heart but this:
How bright will be my bower
When all is finished; my job it is
To see each perfect flower
Curve itself up to the tool's harsh kiss.

"How shall I end the thing I planned?
Such knots are in the wood!
With quivering limbs I stoop and stand,
My sweat runs down like blood—
I have driven the chisel through my hand."

Have I tackled something which I cannot finish?

There were people opposed to wood in bridges and trestles at the turn of the century. Their experience with untreated timbers when there was complete exposure to the weather without roof cover had proven that wood was not a permanent construction material.

All reactions are negative until there is understanding. They did not understand that preservative treatments of the right kind and amount, applied by the right method, could make wood a permanent construction material. Some 60 years later, this fact is well understood.

Structural timber in bridges did not disappear. There are today in excess of 1800 miles of timber bridges in service; this is roughly 40 percent of railroad bridges of all types. It is a general practice to preservatively treat these timbers.

Solid-sawn and glued laminated structural timbers in these bridges are both derived from wood, but there are important differences. Unit and allowable working stresses differ. Cross-sectional dimensions, moisture content, stability under moisture content changes, preservative treating procedures, and construction details differ. Laminated members can be cambered; solid-sawn cannot. Greater lengths, curved shapes and heavier load-carrying capacities are possible with the laminated timbers.

Solid-sawn timbers for ties, caps, stringers, posts, braces, and piles are common; glued timbers will be used in ever-increasing numbers.

Typical Timber Bridges—Installed Since 1944

1. Eleven glued laminated pine stringers were installed in 1944 as one span in a ballasted-deck bridge on the Texas & Pacific Railroad near Woodlawn, Tex. After more than 20 years of service, they are in excellent condition although glued with a phenol-resorcinol waterproof adhesive just a year and a half after phenol-resorcinols had been offered for experimental use. Glue lines were cured above 180 F for 12 hours; the members were treated after surfacing to a net retention of 15.5 lb per cu ft of distillate creosote.
2. The central three-panel portion of an open-deck trestle at Alexandria, Va., owned by the Southern Railway, has southern pine laminated timbers glued in 1945 and treated with 80–20 creosote coal tar solution to a retention of 15.9 lb per cu ft. Four laminated pine caps had top and bottom laminations of red oak for greater bearing strength. Curing conditions were the same as for the 11 Texas & Pacific stringers.
3. The Loon Lake highway bridge timbers near Reedsport, Ore., built by a county highway department, were laminated from FCAP-treated Douglas fir in 1948.
4. In 1956 and 1957, two bridges were built across the Toutle River on a logging railroad serving the Mt. St. Helen's operation. Each 60-ft span has four glued laminated Douglas fir stringers pressure-treated with 50–50 creosote solution.
5. A combination highway-railway bridge was built in 1949 at Culp Creek, Ore., using laminated Douglas fir pressure-treated after gluing with 50–50 creosote-petroleum mixture.
6. Rose Lodge Bridge across the Salmon River near the Oregon Coast.
7. Smith River Bridge near the town of Reedsport, Ore.
8. Bridge across the Wilson River near the town of Tillamook, Ore.
9. Two bridges across the Big Nestuces River near the Oregon Coast, one at Beaver and the "Shorty Farmer" bridge.
10. A large multiple-span logging bridge across the Kootenai River near Libby, Mont.
11. Soda Springs Trail footbridge of the U. S. Forest Service near Mt. Ranier in Washington.
12. Three footbridges in Madison, Wis.: at the U. S. Forest Products Laboratory, the University of Wisconsin Campus, and across the Yahara River.

The performance of glued joints in these timbers has been excellent, especially where the members had been pressure-treated with creosote, creosote-petroleum oil solution, or pentachlorophenol in heavy oil, prior to installation.

The oil-borne preservative leaves a coating of exuded oily material on the surface, protecting the wood from rapid wetting and drying and reducing swelling and shrinking stresses at the surface. Even after the oily exudation has largely eroded away, the oil-borne treatments provide sufficient water repellency to reduce checking and delamination. The water-borne preservatives do not provide the same degree of protection.

AREA Committee 7-sponsored research on effect of load position and repeated loads to 2 million cycles, applicable to bridge stringer and crane runway beams, has shown that the published unit horizontal shear stresses for Douglas fir and Southern pine are conservative. As the load position from supports increases, however, there are greater deflections and lower static and repeated-load strengths. As with investigations on the effects of taper and the effects of notches in wood members, the importance of the combined stress effects of bending, shear and tension parallel-to-grain is apparent.

Four series of tests, including solid-sawn and glued laminated stringers, of Douglas fir and Southern pine, have been completed. Twenty-our additional laminated Southern pine stringers have just been shipped from Peshtigo for Committee 7 research-testing. Twelve untreated stringers are here in Chicago at the AAR Research Center; the other twelve are in Orrville, Ohio, for preservative treating with creosote prior to their arrival in Chicago. Testing will compare strengths of untreated and treated stringers, at two different retentions, under static and repeated loadings, and it will check the influence of a 1 in 10 slope of grain for interior laminations of 6 stringers in relation to the 1 in 16 and flatter slope of grain of the other 18 stringers.

In 1953, the report on Assignment 7 of Committee 7—Wood Bridges and Trestles, stated:

"While glued laminated timber is proving satisfactory, it is rather expensive compared to the solid-sawn timber. Should the time ever come when it is impossible to obtain large-size timbers, glued laminated timber may come into general use."

My assignment now appears possible to complete. We are 15 years beyond 1953; this is a good time to look at "The Future of Timber in Railroad Bridges."

INTRODUCTION

With proper design, construction and in-service usage, wood is a permanent construction material. No competitive material has all its advantages. It is remarkable for its beauty, versatility, strength, durability and workability. It possesses a high strength-to-weight ratio, performs well at low temperatures, withstands substantial overloads for short periods, has low electrical and thermal conductance, and it resists the deteriorating action of many chemicals that are extremely corrosive to other building materials.

One material may equal wood in stiffness, but lacks its ability to absorb shock. Another may rival it in strength, but fails on the point of workability. A third may rank well with wood in lightness of weight, but fails to measure up in ruggedness or in low cost per pound.

Glued laminated timber has advantages over solid-sawn timber, eliminating or minimizing most problems associated with seasoning-in-place. It has bestowed new structural and architectural freedoms upon the designer.

But there is no perfect material or product for any given use. Wood has some characteristics that require special attention. It is combustible, changes dimensions with changes in moisture content, and it will decay or be damaged by insects under certain conditions. If these characteristics are recognized and are kept in mind when designing, fabricating and using it in service, wood will serve with complete satisfaction.

In this timber design, construction and usage there are some ills deserving of our attention. In fighting against them, we also have an obligation to fight for something specific. For the privilege of protesting against something which we consider wrong, we are obligated to reshape things so they become right. We will not discard the major share which others before us have developed. We will add to, and in some cases, modify that which is with us today.

As chairman of the American Institute of Timber Construction Research Committee, I know it is the intention of the glued laminated timber industry to search for beneficial change and to use this research to improve the position of wood in structures—railroad bridges included.

Your presence indicates that you are interested in these changes that are taking place in design criteria, fabrication and construction practices, and in-service usage. They will influence the future of timber in railroad bridges and all other construction where timber's inherent properties make it a functional, economical and durable construction material.

I am going to cover, one by one, the three phases of structural glued laminated timber—design, construction and in-service usage—and in that order. I will cover each of the three, for each is just as important as the others.

DESIGN

Most structural materials are essentially isotropic, with approximately equal strength properties in all directions. Wood has three recognized grain directions—longitudinal, radial and tangential. It has different strength properties parallel and perpendicular to grain. Tensile, bending and compressive strengths are greatest parallel to grain and the least across the grain. Shear strength is least parallel to grain and the greatest across the grain.

The several species are to wood what alloys are to metals. Consideration must be given to the most suitable timber species for a particular assignment. Certain combinations of adhesive, treatment and wood species are compatible; other combinations are not. As each species has certain advantages, so does each adhesive, each preservative and each method of treatment have its advantage.

The "Timber Construction Manual" authored by the American Institute of Timber Construction, was published by John Wiley and Sons, Inc., New York, in 1966. It should prove helpful to those who design in timber.

Wood-Moisture Relationships

Wood is unlike most structural materials in regard to the cause of its dimensional changes. For wood, these changes are primarily from a gain or loss of moisture and not from changes in temperature. Expansion joints are seldom required for wood structures to permit movement from temperature changes. Heavy timbers in structures can withstand extreme temperatures without collapse. Consideration must be given, however, for changes in dimension if there are to be wood moisture content changes.

The final moisture content of wood is dependent upon the relative humidity and the temperature of the surrounding air. Out-of-doors there is also rain, wind, sun and frost to act directly upon the wood. Within buildings, poor environmental conditions may be created for wood unless proper consideration is given to heating, cooling and ventilation. In designing with wood, one must properly define the conditions of use. This includes the moisture content level which the wood will attain in service.

When the moisture content of wood goes above 20 percent for repeated or for prolonged periods, it is subject to attack by decay fungi. If wood is installed wet and subsequently dries or becomes wet after being installed dry and then dries again, there can be changed dimensions and sometimes distortion and twisting. If wood remains above 20 percent moisture content, it will decay unless properly preservatively treated.

Solid-sawn timbers, kept free from decay and insect attack, exist in structures hundreds of years old. There is every indication of an indefinitely long life for this wood.

When the proper lumber and adhesive, laminating equipment and procedure have created a high-quality laminated timber, and the construction details preclude decay and insect attack, laminated timbers are permanent. When completely subjected to the elements, or other conditions of free water, or high relative humidity, where decay is possible, a preservative treatment is a necessity.

Design Stresses for Glued Laminated Timber

Strength properties for a species can be carried out from either of two viewpoints. First, tests can be conducted on full-size members containing defects; practically all structural uses involve members of this character. Second, tests can be made on small, clear and straight-grained specimens to provide preliminary data and then various considerations can be made to establish the strength of the structural members. For the first viewpoint, the results apply only to the particular combination of characteristics existing in the large test members. To determine the strength for other combinations requires an endless testing program. The second viewpoint, the one generally accepted, establishes strength properties for each species, with the application of general rules to cover the specific conditions involved in each usage.

Fundamental Considerations

The strength and variability of clear wood of different species are presented in ASTM D 2555–66T. Starting from the average strength of clear wood and recognizing variability in this strength, it is then necessary to apply, in order, the fundamental considerations of duration of load, size of member, moisture content, factor of safety, density or rate of growth, and stress concentrations for shear and shear deflection before arriving at a basic stress.

Basic stresses are general indicators of the comparative properties between species. They do not reflect the quality or grade of the material from which structural laminated timbers are fabricated, nor do they reflect specific design requirements.

Quality Considerations

Adequate consideration for size and location of knots and for general slope of grain and for local deviations of grain, plus other growth characteristics, such as shakes, splits, checks, and end joints, results in modifying the basic stress into a unit stress. Industry associations, when publishing stresses for wood, commonly show this unit stress value.

Design Considerations

To arrive at allowable working stresses for specific design requirements, further modifications are usually required. Modifications for duration of load, size of the finished member, and moisture content in use are made when duration of load, size of member or moisture content in service are different than that used in arriving at the basic stress. Other design considerations are temperature, treatment, form or shape of cross-section, lateral support conditions, curvature in laminated members, and adjustments for shear deflection in beams.

Research in Structural Timber

Research efforts continue to build our confidence in established procedures for timber design, but they also show a continuing need for reform. These changes in wood engineering are required primarily because members are getting bigger. Problems on the railroads come from equipment becoming heavier and loads becoming bigger. Electric transmission structures are becoming huge. Ocean-going ships are larger, with all kinds of new design problems. Roofed athletic arenas are getting bigger; there is a proposal for an 840-ft-diameter dome.

L. J. Markwardt, former AREA Committee 7 member, today a very active chairman of the AITC Technical Review Board, and always one with a few lines of poetry relating to wood, stated in his "Wood as an Engineering Material," Edgar Marburg lecture in 1943:

> "Large streams from little fountains flow,
> Tall oaks from little acorns grow."

These words can be changed to:

> "Large streams from little fountains flow,
> Huge timbers from little laminations grow."

The design criteria applying to relatively small lumber sizes do not necessarily apply to large timbers. We will continue to apply fundamental, quality, and design considerations to average strength values for small, clear and straight-grained test specimens. We then obtain, respectively, the basic, unit and allowable working stresses for structural timbers. However, we will end up with allowable working stresses for large timbers differing from those for boards and dimension lumber, or small-cross-section timbers.

Twenty years ago it was known that deep beams showed lower stresses at failure than did shallow beams. Box or I-beam sections developed lower stresses at failure than beams of solid square or rectangular cross section. A "depth or height effect" has been applied cumulatively in design to other strength-reducing factors since 1960. Research has now developed a statistical strength theory which relates bending strength to the depth, length and the loading method for a beam. To compare this new "size effect" theory to older theories relating change in strength only to depth, it is convenient to use span-depth ratios for typical beams, eliminate length from formulas, and thus retain only depth and method of loading. There is no great change to apply to railroad bridge members 12 or 16 in. deep. The future will undoubtedly involve much larger wood members.

Wood, being a non-homogeneous material, is always difficult to describe. But we must describe it and do a better job than in the past. We cannot continue to describe a compression grade and say that material so graded may also be used, without modification, for a bending member or even a tension member. Growth characteristics are more detrimental to tensile strength than to compressive strength. However, published ratios for slope of grain do not say this. It was not necessary to be concerned about these differences in the past, but today, and in the future, things are different; this is mainly because of size.

Wood is excellent in compression parallel-to-grain, but compression is also a troublesome stress due to the need to design against buckling. A very arbitrary depth-width limitation has existed in timber design ranging from about 2:1 to 7:1. For the 7:1 ratio, both edges of a bending member, top and bottom, are to be held in line. These procedures have their origin in the days of obtaining sawn timbers from a log where the largest size, let's say 12 by 24 in., had a 2:1 ratio of depth to width. No such limitations exist today in laminating. An almost unlimited size potential dictates that research continue to investigate systems needed to hold ends of members in line and the bracing required to hold the compression edge of supporting members from buckling. The possibility of buckling failures in deep beams is dependent upon beam depth and length; the slightest transverse nailing between deck members attached to the beam may furnish enough stability to eliminate buckling as a possible mode of failure.

In tapered bending members, bending, shear and vertical stresses can occur at one point, and the effect of combined stresses needs to be considered in design. Where load is applied at an angle to the grain, and tensile strength is a result of tensile strength parallel-to-grain, tensile strength perpendicular-to-grain and shear strength parallel-to-grain, there is a need for additional research and a better understanding of the subject.

The effect of local cross grain—those local deviations of grain that bending grades tell us we may disregard—should be researched carefully with reference to the percentage of the cross section which they cover in a tension grade.

Bending grades will not suffice for areas of a laminated member highly stressed in tension. Research must carefully describe the limits of growth characteristics that may be allowed in tensile laminations.

An AITC test, in existence for a short time in the early 60's, was an alternate to a qualification tension test for end joints under the proposed Commercial Standard for Structural Glued Laminated Timber. This test was quickly dropped because it became apparent, even to those who had proposed it as an alternate, that it was a very impractical and uneconomical method for checking, at most, one end joint in the bottom tensile lamination of a large bending member. Turning this experience around, it is easy to see that in our large bending members it is almost entirely a single bottom tensile lamination which determines beam strength where structural grades of lumber are used; much more research must be conducted to properly describe these tensile laminations and we must up-date the I_K/I_G concept relative to knots.

Post-tensioned laminated wood beams have been fabricated involving high-strength steel strands placed longitudinally in the tension zone, subjecting the beam to a bending moment opposite to that which would be imposed in service. Such beams were about one-third stronger than control beams, with about one-half the variability. Stiffness of the wood members was not changed. A single clear and straight-grained outer lamination has been demonstrated to have a more favorable influence on beam strength than had been generally realized.

Pretensioning laminated beams, with steel plates under tension glued to the outer tensile lamination, show a more beneficial effect than post-tensioned laminated beams. Compared to controls, these pretensioned beams were, on the average, 25 percent stiffer and 75 percent stronger, and the variability was decreased 70 percent. Additional answers must be found relative to creep and stress relaxation.

The tension strength of wood must be established by tests, not only for clear and straight-grained material, but for all structural grades.

CONSTRUCTION

Fabrication—Wood

Wood must be fully understood by the designer; then it must be selected for strength in fabrication, recognizing interplay between properties and uses.

Structural glued laminated timber was never intended to be anything other than the placement of the higher grades of lumber in the areas of greatest stress, with the lower grades also used for overall economy, but using such lower grades only in the areas of low stress.

The better tension grades go on the outside tension face of a bending member. The same grade of lamination is used throughout the cross section of a tension or compression member. For short and heavily loaded bending members, the higher specific gravity material, with good shear-strength potential, is located in the central areas toward the support points where shear stresses are the greatest. In pitched and curved beams, laminations of good shear strength, capable of sustaining forces in tension perpendicular-to-grain should be placed in the inner areas of the curved portion.

Such placement of material is not difficult, but there must be an effort on the part of the laminator—it just doesn't happen.

For crane runway beams, bridge stringers and pitched and curved beams, the use of stiff laminations on the outside with those of lesser stiffness on the inside would surely be an error.

As laminations increase in thickness, members do not become stronger. There could be an increase in specific gravity for the greater lamination thicknesses, but a higher strength would then exist, not because of the greater lamination thickness, but because of the greater density.

Beams fabricated of No. 3 and No. 4 common boards would not show excellent test results. If all material with slope of grain steeper than 1 in 12 were held out, and if several outer laminations each side were "D" selects limited to a slope of grain of 1 in 16 or flatter, there could be good performance. However, this material could hardly be referred to as common boards.

Laminations can be correctly arranged in accordance with stiffness, density, appearance, or some other growth characteristic. By whatever method used, the arrangement must consider the task which the individual laminations and the finished member is expected to perform. A false economy is present if all lumber used is of a grade sufficiently high to withstand the greatest stress. An unsafe condition exists if the lowest grade permissible is to be placed indiscriminately throughout the cross section and the length of the member.

Fabrication—Adhesive

Adhesives exist for thousands of uses, but the ideal adhesive—a single one to handle all wood-bonding tasks—does not exist. Searching forever, we will not find that one ideal adhesive. Research funds and the talent to design adhesives for a particular assignment do exist.

A phenol-resorcinol glued assembly must be kept under gluing pressure a length of time dependent upon glue-line temperature. The rate of chemical reaction taking place between liquid resin and powdered hardener is increased at higher temperatures and decreased at lower temperatures. A long pot life and a short pressure period are desirable; a low temperature helps the first and hinders the second. Temperature is, therefore, both ally and enemy to the laminator. Many laminators believe that the best system involves keeping the resin cool during storage, mixing the resin and hardener in an insulated container, spreading the mixed adhesive and then heating the glued joint after the members are under gluing pressure. Some laminators cure at 110 F, innermost glue line temperature, insisting that no gluing can be accomplished, with phenol-resorcinol water-proof resins, with the aid of elevated temperature curing. The truth is that neither 180 F, 150 F, nor 110 F, is required. Room temperature curing is possible.

Wood is an excellent insulator, and a long clamp period is required before elevated ambient temperatures can penetrate the wood, reach the innermost glue line and cause adhesive to set.

The greatest developments in structural timber gluing will come from cooperative efforts of three parties—the adhesive manufacturer, the equipment manufacturer, and the laminator—all working together with fast, room-temperature-curing, phenol-resorcinol adhesives to produce economical structural glued laminated timbers.

Laminating—Procedure

Several methods have been used to bring heat to glue lines:

1. Heat may be applied to the surface of the wood.
2. Radio-frequency current can generate heat in the wood or the glue line itself.
3. Low-voltage resistance heating can be employed where current passes through a strip of thin metal and the temperature of the wood and glue line nearby is raised.
4. Lamination surfaces can be preheated so as to increase the reactivity of the adhesive when applied.

Curing the adhesive at room temperature has several advantages over gluing systems utilizing elevated-temperature curing:

1. The good insulating properties of wood need not be working against you.
2. The equipment for elevated glue line temperatures is not required.
3. There is no elevated temperature to consider insofar as possible injury to the wood is concerned.

There is a wide choice of curing temperatures based upon pot life, assembly time and pressure period needs.

Room temperatures in the range of 68–86 F allow pressure periods to depend primarily upon the reactivity of the mixed adhesive. Control of the adhesive before application to the wood is by cooling; once applied to the wood, the reactivity of the adhesive hastens the set.

Gluings in structural timber laminating can be divided into three distinct types:

1. First, the gluing surfaces are less than about 3 in. in width. This is a high-frequency operation; it is a typical edge-gluing or end-gluing operation but seldom a face-gluing task.

2. Second, the gluing surface is 3⅛- or 5⅛-in. wide and the species is a softwood. High-frequency curing is now considerable in first cost, expensive to operate and maintain, limited in production capacity per machine, and there are limitations on the size and shape of member which can be cured.

The 3⅛-in. members will seldom exceed 24 in. in molded depth and 30 ft in length; the 5⅛-in. members will seldom exceed 36 in. in molded depth and 40 ft in length.

Bridge stringers, using 8- or 10-in.-wide lumber, for simple or two-span construction, could be of this second type. They are often less than 20 and 40 ft, respectively, and are straight. They are of short length even though the width is greater than the earlier-mentioned 3⅛ or 5⅛-in. width.

3. Third, the gluing surface is still wider than for Types 1 and 2; the species is a dense hardwood, there is a large cross section, it is sharply curved, or it is of a variable molded dimension along its length, or it is a softwood of moderate size to large size, with or without curvature. The hardwood is ordinarily cured at elevated temperatures; the softwood is usually assembled and cured at room temperature. A wide range of sizes and shapes are glued, with clear-spanning members of 100, 200 and 300 ft common today; these are large, shop-grown timbers up to about 12 in. in width and 7 or 8 ft in depth.

For the second type of gluing, there has been a need for a method of handling extremely reactive phenol-resorcinol resin adhesives for application to softwood laminations curing at room temperature in quick-acting forms or presses. The adhesive cure rate would be chemically accelerated at the expense of pot life.

To meet this need we developed equipment to automatically proportion, mix and dispense a reactive phenol-resorcinol adhesive that is too reactive to be handled with conventional mixing and spreading equipment. It can automatically purge or cleanse itself prior to the next usage or before mixed adhesive is allowed to set up with its parts. This equipment is the first part of a two-part system, the other part being the quick-acting press, to make it possible to rapidly load and unload the fast-curing assembly.

Mixed adhesive is available at short notice; there is extremely accurate proportioning of resin and powder; greater control in mixing; control of temperature of resin and of mixed adhesive at delivery to the applicator; and automatic purging and cleanup. A small amount of waste exists in start-up and cleanup. The adhesive is delivered under positive pressure, permitting use of a wide variety of applicators. It reduces labor and plant space requirements.

Briefly, this equipment cools, proportions and delivers a liquid resin; proportions and delivers a powdered hardener; mixes resin and hardener; delivers the mixed adhesive under pressure to the adhesive applicator, and it purges itself of mixed adhesive before the pot life is exceeded, or when delivery of adhesive is no longer desired.

Field Construction

Materials, the workmanship on materials and the care used to protect materials during the building period influences subsequent performance. All wood members should be received with reasonable care at the construction site and be stored neatly. To prevent surface marring and damage to wood members, they should be lifted or rolled on dollies or rollers when being taken out of railroad cars. Trucks should be unloaded by hand or by crane. Do not dump, drag or drop members. During unloading with lifting equipment, use fabric or plastic belts, or other slings that will not mar the wood. If chains or cables are to be used, provide protective blocking or padding.

Members should be elevated above the ground when stored prior to erection so that air may circulate around all sides of them. Where appearance is a consideration, the top and all sides of each storage pile should be covered with a moisture-resistant covering that provides protection from the elements, dirt and job-site debris. Individual wrappings, when used, should be slit or punctured on the lower side to permit drainage of water that accumulates inside the wrapping.

Erection of timber framing requires experienced crews and adequate lifting equipment to protect life and property and to assure that the wood is properly assembled and not damaged during handling. Handling and storage methods for wood members at a construction site should be related to the end use of the particular members. In general, timbers should not be delivered to the construction site long before they are ready to be incorporated into the structure. The moisture content level of the member, specified in the design, should be maintained, making provision during installation for only that expansion or contraction which is to be anticipated in the design.

The degree of covering during shipment will naturally differ for a prefinished member to serve in a church and a treated stringer for the out-of-doors exposure of a bridge.

IN-SERVICE USE

Dry condition of use stresses are for normal loading where the wood moisture content is less than 16 percent. Dry-use adhesives can then perform with satisfaction.

Wet condition of use stresses are for normal loading where the wood moisture content is 16 percent or more. Wet-use adhesives are required where the wood moisture content exceeds 16 percent for repeated or prolonged periods of servicee.

The original design should always define the type of service condition related to the intended use of the structure. The range of relative humidity must be defined to describe conditions within a covered structure. There may be exposure to free water and the out-of-doors elements where the wood member is fully exposed to the weather without roof cover. The structure may be a residence, industrial plant, swimming pool enclosure, bulk storage facility, etc. Structure usage should not be changed without a re-evaluation of the influence of service conditions upon the design.

The design of a structure probably has more to do with future performance than the construction or the in-service usage. However, these three—design, construction and in-service usage—are so interrelated that one cannot be considered without the others.

Coatings

The primary maintenance problem with out-of-doors steel and concrete structures is the protective coating. It is only slightly different for wood. In fact, there is only one reason covered bridges were built—the cover was to protect the bridge itself—for in those days the wood in bridges was not preservatively treated. Wood lasts a long time in water and a long time in sunshine; under certain conditions it has difficulty withstanding the mixture.

The nature and extent of protection needed for wood exposed out-of-doors requires an understanding of two deteriorating influences—weathering and decay. These actions, if permitted, will finally cause complete disintegration of wood.

Weathering and decay are not usually found in the same place. Dry wood will not decay because the fungi must have water to live. Weathering is usually found where the wood, as a whole, remains fairly dry. The surface layers of the wood periodically take up moisture, but drying occurs before the water can penetrate to the interior of the wood and support decay. Protection against weathering can be provided by coatings, but coatings do not preserve wood against decay.

Wood fully exposed to the weather, without roof cover, will require periodic renewal of any applied coatings. If clear finishes are used, a more frequent need for refinishing can be expected, especially where the usage is without roof cover and there is full exposure to the weather. It is to be understood that such exposed wood will be preservatively treated before coating and subsequent exposure.

CONCLUSIONS

Timber has a combination of strength and stiffness, light weight, and low cost per pound that will dictate that it be considered in all future railroad bridge and trestle construction. For this function, preservatively treated timber is appropriate; it is durable and easy to work, and no periodic painting is required in this usage.

Research has not yet developed a satisfactory fire-retardant treatment for timber bridges and trestles. The hazard of destruction from fire still exists, but there are many 40-year-old timber structures in service. Future timbers will be large, fewer in number for a particular construction, and will be spaced farther apart. The glued laminated heavy timber member will be an excellent risk against destruction by fire.

Increased usage of timber will be due not only to the unlimited architectural and engineering possibilities in structural glued laminated timber, but to significant improvements in design criteria, wood grading, in faster room-temperature-setting adhesives, in laminating techniques, in field construction, and better attention to in-use service conditions.

Standard widths should be used whenever possible; also a laminated member depth should be a multiple of standard lamination thicknesses. The same grade should not be demanded throughout the depth and length of most members. Depth-width ratios should take advantage of the economy of deep but narrow sections whenever the compression flanges can be well braced in the construction.

Wood is the greatest renewable resource in the building materials field. More trees can always be grown; iron ore, when gone, is gone forever. Wood is man's oldest construction material but is still being improved and refined for particular needs.

To serve attractively has also become as important a part of the commitment of a product as its requirements for efficiency and economy. The three-level interchange on U. S. Highway 16 near Keystone, S. Dak., in the wooded Mt. Rushmore area, is an example of timber structural framing designed to harmonize with a rugged setting. Structural glued laminated timber, treated prior to gluing with pentachlorophenol by the Cellon process, has permitted the wood to remain almost completely natural in color and appearance.

The strength, economy and good appearance of timber will be used in building bridges in the future. (Applause)

(During his address Mr. Rhude presented many colored slides, none of which is reproduced herein).

Chairman Sartore: Thank you, Mr. Rhude, for a very timely and informative presentation. Most of us believe that timber structures can be economical. We as engineers have a responsibility to our managements to provide the most economical structures possible, and certainly timber must be considered where circumstances permit. Thank you once again, Mr. Rhude, for taking the time from your busy schedule to make this interesting presentation.

Mr. Vice President, this concludes the report of Committee 7. (Applause)

Vice President Wilson: We thank you, Mr. Sartore, for that interesting presentation. The efforts of yourself and the members of your committee are very much appreciated.

Mr. Rhude, we thank you for being with us and for your comments on the future of timber in railroad bridges. The railroads have always been a major consumer of timber and lumber and you may be sure they will continue to be for many years to come. Again, thank you for your interesting and timely talk.

Mr. Sartore, your committee is excused with the thanks of the Association.

Discussion on Impact and Bridge Stresses

For report, see Bulletin 611, pages 449–452)

Vice President Wilson: Committee 30—Impact and Bridge Stresses, will be our next reporting group. The chairman of this committee is N. E. Ekrem, bridge engineer, Great Northern Railway, St. Paul, Minn.

Mr. Ekrem, you may proceed when your committee is in place.

Chairman N. E. Ekrem: Mr. Vice President, members of the Association, guests:

A year ago, I made reference to the death of one of our highly respected members, Professor Armour Townsend Granger. His memoir, prepared subsequent to that time, appears with this year's report in Bulletin 611.

This year we reported on three of our four assignments. These reports are presented as information. For my oral presentation today I would like to comment briefly on each assignment.

Assignment 1—Steel

Chairman Ekrem: Much of the recent work on this assignment has been directed toward the study of stresses in steel truss spans. Two truss span reports were reviewed and approved for publication during the year and field tests for another were conducted.

Publication of an Engineering Report is the culmination of much work by the AAR Research Center staff and our committee. The Research Center staff conducts the field investigation, digests the data, and writes the report—all entailing some measure of liaison with this subcommittee.

The subcommittee makes a detailed preliminary review of the report, after which final review and approval becomes a function of the entire committee.

A new philosophy regarding formulating conclusions for individual reports has evolved during this past year. In the past, the subcommittee drafted conclusions for each report. Because of varying conditions encountered in separate research projects, the conclusions would not always be entirely consistent among the various projects, and in committee discussions we often referred to them as observations rather than conclusions. It is our present opinion that, while it is proper to record observations and note trends apparent in individual tests, it is wiser to develop conclusions from the results of a series of tests covering a broad range of tests.

In the case of truss spans, we need several more tests to broaden our range, after which we will prepare a summary report setting out conclusions and, if such is indicated, offer recommendations for specification changes.

Under Assignment 1, we are also progressing studies on the frequency of occurrence of maximum stress, an important factor in the problem of fatigue.

Assignment 2—Concrete

Chairman Ekrem: Subcommittee 2 has been continuing its studies on longitudinal forces, working toward preparation of a summary report on this subject.

In hand are the reports on 13 separate tests conducted in past years, each having its own set of conclusions. The subcommittee is reviewing them in an attempt to develop valid conclusions from an overall perspective. We were not able to complete this study as anticipated, but hope to do so during the following year.

Last year was the first one for some time that we did not progress our studies in the field of prestressed concrete bridges. However, as noted in our report, plans have been laid for their immediate resumption.

Assignment 3—Timber

Chairman Ekrem: For the last several years Subcommittee 3 has been unable to progress its assignment because funds were not allocated for needed research. While such was the case again in 1967, I am happy to report indications are that our budgetary recommendations in this area will receive favorable consideration so research can be carried out next summer.

This recognition of our needs is progress in itself and worthy of note.

It remains for this subcommittee, collaborating with Committee 7 and the AAR Research Center staff, to translate plans into action and I am confident the results will be well worth while.

Assignment 4—Electronic Computers

Chairman Ekrem: The electronic computer is a relatively new tool but is fast coming of age. Subcommittee 4 is progressing its work under this assignment in selected areas to provide data and programs that are useful to the bridge engineer and his staff in solving problems involving determination of stresses in railroad structures.

The truss program developed last year by Professor E. N. Wilson is a start in the general field of stress analysis. This particular program will be expanded next year, and our overall planning includes, among other things, programs for rating existing truss spans and girder spans.

The tables produced as a result of our program for rating heavy-duty equipment have found wide usage in determining if heavy loads should be permitted to pass over light-design bridges. The set of tables, originally produced in 1960 has been expanded each year since. In many cases individual railroads have procured the program and are producing their own tables as special loads come up for consideration.

I would like to call your attention to the fact that programs developed to date are available from the AAR at a nominal cost.

All who have access to a computer should make use of this new tool—and soon if they are not now so doing.

Chairman Ekram (continuing): Next I would like to introduce our subcommittee chairmen:

D. S. Bechly, engineer of bridges, Illinois Central Railroad, is chairman of Subcommittee 1—Steel.

J. A. Erskine, assistant bridge and building engineer, Gulf Mobile & Ohio Railroad, is chairman of Subcommittee 2—Concrete.

C. V. Lund, assistant chief engineer—structures, Chicago, Milwaukee, St. Paul & Pacific Railroad, is chairman of Subcommittee 3—Timber.

E. R. Andrlik, bridge designer, Atchison, Topeka & Santa Fe Railway, is chairman of Subcommittee 4—Electronic Computers.

I am indebted to these men and to the members of their subcommittees who have contributed so greatly to the work of Committee 30 during the last three years, and want to thank them for their splendid cooperation.

Now, it is my pleasure to introduce our new vice chairman, M. Noyszewski, chief designer, Illinois Central Railroad.

Finally, I want to introduce P. H. Montgomery, division engineer, Norfolk & Western Railway, who will take over as chairman of Committee 30. Paul has been a very cooperative vice chairman. Prior to becoming vice chairman he was chairman of one of our most active subcommittees. Our committee chairmanship will be in good hands.

Vice President Wilson: Thank you, Mr. Ekrem and the members of your committee for that report and the efforts of all of you this past year.

Mr. Ekrem, we appreciate the able and dedicated leadership which you have given to Committee 30 for the past three years. As you are relieved of your responsibilities as chairman, we are pleased to welcome Mr. Montgomery as your successor, and Mr. Noyszewski as the new vice chairman of the committee. We are satisfied from their past performances that under their direction the important work of Committee 30 will continue.

Mr. Montgomery, as a symbol of your new authority and to assist you in conducting the meetings of your committee, I would like to present you with this chairman's gavel. The inscription reads:

"P. L. Montgomery, Chairman, AREA Committee 30, 1968–1970".

(The gavel was presented to Mr. Montgomery.) (Applause)

Vice President Wilson (continuing): Your committee is now excused with the thanks of the Association.

Discussion on Cooperative Relations with Universities

(For report, see Bulletin 610, pages 277–296)

Vice President Wilson: The next report will be given by Committee 24—Cooperative Relations with Universities, the chairman of which is R. H. Beeder, chief engineer system, Atchison, Topeka & Santa Fe Railway, Chicago.

Mr. Beeder, as soon as your committee has occupied the platform, you may proceed with the business at hand.

Chairman R. H. Beeder: Professor W. W. Hay of our committee has prepared for publication in the Proceedings a brief memoir in honor of the late Herman E. Kirby, a Member Emeritus of Committee 24. The memoir, which follows, calls attention to a more complete memoir prepared for publication with the report of Committee 22 in the Proceedings.

Herman E. Kirby
1903-1968

With the passing of Herman E. Kirby on January 28, 1968, retired cost engineer-system of the Chesapeake & Ohio Railway, Committee 24 has lost a good friend and loyal committee member. His contributions to the work of this committee were recognized by his appointment to a vice chairmanship, shortly before ill health forced his retirement, and his election as a Member Emeritus of Committee 24. Among his many contributions to the work of this Committee, Herman Kirby may best be remembered for the Recruitment Brochure. Under his guidance as subcommittee chairman, a brochure was prepared that has served the industry well and gained national recognition in the publishing field.

Committee 24 notes the extended memoir prepared by the members of AREA Committee 22. We fully concur in the sentiments of appreciation and loss therein expressed and wish to join with Committee 22 in recalling and honoring the ability, integrity and warm humanity of their friend and associate.

Chairman R. H. Beeder: Mr. Vice President, members, and guests:

The report of the activities of Committee 24 for the past year is contained in Bulletin 610 on pages 277 to 296, incl.

The vice chairman of Committee 24, Professor Vincent J. Roggeveen of the Department of Civil Engineering, Stanford University, is unable to be with us today.

Your Committee on Coperative Relations With Universities is currently working on eight subjects:

Assignment 1 covers our charge to stimulate railway managements to bring more graduates of colleges and universities into railway service, and to foster their continued employment so as to retain them in railway service. This assignment is under the chairmanship of A. V. Johnston, chief engineer, Canadian National Railways. Mr. Johnston, will you please stand and be recognized.

Assignment 2 covers our work in stimulating a greater interest in the science of transportation among college and university students. This assignment is under the chairmanship of Dr. R. H. Lee, assistant professor of structural engineering, Purdue University. Dr. Lee was unable to be with us today.

Assignment 3 covers all phases of the cooperative system of education, including summer employment of college and university students in railway service. This assignment is handled under the chairmanship of Professor W. A. Oliver of the Department of Civil Engineering, University of Illinois. Professor Oliver was unable to be with us today also.

Assignment 4 is being reactivated this year to update and revise our recruitment brochure entitled "The Railroad Industry—A Challenge and Opportunity for Engineering Graduates." The present issue of our recruitment brochure is more than five years old. This assignment will be undertaken by Bruce G. Anderson, chief engineer, Great Northern Railway. Mr. Anderson, will you please rise and be recognized.

Assignment 5 proposes ways in which railroads can cooperate with universities in developing research and is under the jurisdiction of Harold E. Hurst, division engineer, the Milwaukee Road. Will you please stand and be recognized, Mr. Hurst.

Assignment 6 covers our work in formulating procedures for orienting and developing newly employed engineering personnel, and is under the direction of W. T. Hammond, engineer of standards of the Penn Central. Mr. Hammond was unable to be with us today.

Assignment 7 covering the stimulation of interest in college and university staff members in current railroad problems and practices, including AREA membership, is guided by Professor Roggeveen, who is too busy at Stanford today to be with us.

Assignment 8 covers changes in engineering education and their implications with respect to employment of future graduates by the railway industry. This subcommittee is under the chairmanship of Jack F. Davison, assistant to chief engineer, Canadian National Railways. Will you please stand and be recognized, Mr. Davison.

Chairman Beeder (continuing): As announced in the Convention Program, your committee has a special feature as part of our presentation here today. Our speaker is Dr. George A. Hawkins, vice president for academic affairs, at Purdue University.

Inasmuch as I am a native Coloradian, it gives me special pleasure to tell you that Dr. Hawkins was born in Denver. He received his B.S. degree in mechanical engineering, with distinction, from Purdue University in 1930, his M.S. in 1932, and his Ph.D. in 1935.

While pursuing his graduate work Dr. Hawkins taught at Purdue and then later served as assistant professor of mechanical engineering from 1936 to 1938; associate professor from 1938 to 1942, and professor beginning in 1942.

Much in Dr. Hawkins' career exemplifies his dedication to engineering research and development, for as early as 1932 he worked as a research assistant at the Engineering Experimental Station, and was research associate from 1936 to 1944. Our guest was Westinghouse research professor in heat transfer from 1944 to 1953, and served as research director of the Small Arms Division, United States Army Ordnance Experimental Station, during the period 1942 to 1951. He became assistant dean of the Graduate School in 1947, and then acting dean in 1948. Dr. Hawkins was visiting professor of engineering at the University of California during the period 1949 to 1950. He was then associate director of the Engineering Experiment

Station at Purdue from 1950 to 1953, and served as director of that Station from 1953 to 1961. Our guest was dean of engineering at Purdue from 1953 to 1967, when he was appointed to his present position as vice president for academic affairs of Purdue University.

Dr. Hawkins has also taken an active part in a number of technical societies, including the American Society of Mechanical Engineers, the American Institute of Chemical Engineers, the Army Ordnance Association, and the American Society for Engineering Education. In his work in the the American Society for Engineering Education, Dr. Hawkins co-authored that recently published report on "Goals of Engineering Education." In this study and report he was director of the undergraduate phase of study.

A great many awards and honors have come his way because of his dedication and knowledgeable approach to the solution of problems in engineering, particularly to those related to engineering education. In reviewing the tremendous career of Dr. Hawkins, I presume I might say that only the addition of some railroad experience could make his accomplishments more impressive to an audience such as we have here today.

Gentlemen, it is my privilege to present to you the vice president for academic affairs of Purdue University, at Lafayette, Ind., Dr. George A. Hawkins.

Education for Tomorrow

By GEORGE A. HAWKINS
Vice President for Academic Affairs, Purdue University

I. Introduction

Before presenting several recommendations regarding the design of the educational programs which must prepare our students for a useful future career, I should like to briefly consider some of the powerful forces we must be aware of. These forces which are influencing our lives are:

1. The time elapsed between a scientific discovery and the manufacture of a piece of hardware based on the discovery is decreasing.
2. The systems we are designing and using are growing in complexity.
3. The rate of obsolescence of man and devices is increasing.
4. The increasing role of computers is frightening.
5. The significant increase in scientific and technological information and the use of the data are awe-inspiring.

1. The Time Elapsed Between a Scientific Discovery and the Manufacture of a Piece of Hardware Based on the Discovery Is Decreasing.

We need only consider a few examples[1] to illustrate this concept.

Invention	*Time Elapsed in Years*
Photography (1727–1839)	112
Telephone (1820–1876)	56
Radio (1867–1903)	35
Television (1922–1934)	12
Radar (1925–1940)	15
Atomic Bomb (1939–1949)	6
Transistor (1948–1953)	5

[1] Reference, Open Vistas: Philosophical Perspectives of Modern Science, H. Margenau, Yale University Press, 1961.

I cannot foresee any possible reason or reasons for the time interval to ever again increase. This means that the scientist, engineer, and technologist of today and tomorrow must dedicate himself to life-long learning, if he is to cope with the rapidly changing technology.

2. *The Systems We Are Designing and Using Are Growing in Complexity.*

Several comparisons[2] will be made to bring out this point.

a. DC-3:
In this aircraft there were 45 electronic tubes.

Boeing 707:
This aircraft contains over 2,000 electronic components.

b. Constellation:
To qualify the mechanic to handle the electronic gear for the aircraft, it took about 100 man-hours.

Modern jet liner:
1,500 man-hours are required to train a mechanic to maintain the modern jet liner.

c. B-47, -52, -58:
9,000,000 hours of contractor's efforts were required to bring the design of these airplanes to first-flight models for production.

Atlas "D" ICBM:
31,000,000 technical man-hours were required to just freeze the design of this ICBM.

d. The Model T Ford:
Some of we oldsters could take this engine apart with a monkey wrench.

The Mustang:
I, for one, would not even attempt to repair the engine in this car, even if I had all of the special wrenches needed.

e. The old coal and gas stoves:
Almost anyone could operate these devices.

Modern electric stoves have timers to start and stop the cooking so that the housewife can play bridge and go shopping. The fronts are beginning to look like the control panel of an airplane. On my wife's electric stove, there are 24 switches, timing clocks, and temperature indicators and 4 temperature controllers.

3. *The Rate of Obsolescence Is Increasing.*

We have witnessed, and are witnessing, many examples of obsolescence of men and systems. Examples are:

(1) Obsolescence of Systems

a. Jet power propulsion units have almost replaced piston engines for long air runs.

b. Silk threads produced by worms and used in women's stockings have been replaced by man-made fibers.

c. The small, corner grocery store is rapidly giving away to the supermarket, and the supermarket to the colossal supermarket.

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[2] U. S. Air Force material furnished by Col. A. Higdon.

d. The thrill of hearing the New York Central steam locomotives huffing and puffing while pulling a train up the hill from Lafayette to West Lafayette is only a memory. The diesel locomotives have replaced the steam engines. The gas turbine will probably make heavy inroads during the next ten years into the railroad propulsion field.

[3]It is hard for a man to recognize as progress the elimination of his job.

Because of this the American railroad industry and the AFL–CIO Brotherhood of Locomotive Firemen and Enginemen were locked for almost five years in a controversy which still stands as a classic contest over technological unemployment.

Under the nation's first peacetime compulsory arbitration law, the railroads were given authority to eliminate a certain percentage of the fireman from diesel engines in yard and freight service. The award, however, gave lifetime job protection to most men, and various cushions are provided against their summary dismissal. Time does not permit a presentation of all of the legal negotiations, which finally reached the United States Supreme Court.

(2) Obsolescence of Man

How can the scientist, engineer, and teacher of today and tomorrow keep up to date? This is one of the major questions we must answer. How much time should the engineer, scientist, and teacher budget to keep up to date? Professor Thomas Stelson, professor of civil engineering at Carnegie Institute of Technology stated an answer very clearly, and I quote.

"Unless a graduate of 10 years ago has systematically spent about 10 percent of his time extending his knowledge beyond the level of development achieved in his collegiate training, he will not have value in excess of a new graduate. This assumes, too, that he retains all of his previous training, which is probably far from realistic. If decay from neglect or disuse is also 10 percent per year, an engineer is then faced with the task of growing in new knowledge at the rate of about 20 percent per year to remain of equal value to society. To increase in value at a significant rate, he should probably devote about one-third of his productive hours to self-education and improvement."

4. The Increasing Role of Computers Is Frightening.

[4]"Lord Byron had a flair for poetry and for life, but Lady Byron (the 'Princess of Parallelograms') and their only child—Ada Augusta, Countess of Lovelace—appear to have been more intrigued by mathematics. In fact, Lady Lovelace (1815–52) blazed a trail of her own in the arts of computer analysis and programming.

"She was fascinated by the mathematician Charles Babbage, visited him frequently and listened avidly as he explained his plan for an automatic mathematical machine called the Analytical Engine. She left behind, in detailed notes appended to her translation of an article in French on Babbage's plan, a brilliant description of a machine that 'weaves algebraic patterns just as the Jacquard-loom weaves flowers and leaves.'

"This mathematical machine of counting wheels, gears and cranks was never completed despite fund-raising schemes such as an abortive plan by Babbage and Lady Lovelace to develop a surefire system for betting on the horses. But what was once called 'Babbage's Folly' turned out to be a really smashing idea.

[3] *The Louisville Times*, April 5, 1965.
[4] *New York Times*, Monday, January 9, 1967.

"Babbage (1792–1871), who grew grumpy with age and disappointment, was a mathematics professor at Cambridge in the 1830's. He had a piercing and restless mind, a biting tongue, a visceral distaste for organ grinders, an 'inveterate habit of contriving tools' and side interests in such matters as actuarial tables, economics systems analysis, the pulse beats of animals and colored lights for the ballet.

"This many-splendored genius built a model of a small Difference Engine that evaluated polynomials by the method of taking differences among numbers. He was involved in a project—never finished—to build a bigger Difference Engine when he conceived the grand design for an even more elegant counting-wheel machine, the Analytical Engine.

"It was to have a 'store' to hold information to be processed, a 'mill' to work on the data and a 'control' to provide automatic operation. The control was to be the kind of punch cards introduced in 1801 by the French inventor Joseph Marie Jacquard for automatic loom weaving.

"Machine calculation is at least as old as the abacus, but the history of modern calculators dates to the 17th century, when Napier, Pascal and Leibnitz all built computing devices. Pascal's calculator is particularly important as the protoype of mechanical calculators now being used.

"It remained for Babbage to advance concepts immediately recognizable as having a direct relationship to the way present-day digital computers operate. In Babbage's time, however, the technology for carrying out his ideas simply did not exist.

"More than a hundred years elapsed before the first machine resembling the Analytical Engine was built. This mechanical computer, conceived by Howard H. Aiken of Harvard, was completed with the collaboration of the International Business Machines Corporation in 1944. Two years later came the first electronic digital computer—ENIAC (Electronic Numerical Integrator and Calculator)—designed by J. Presper Eckert and John Mauchly of the University of Pennsylvania."

The computer is affecting every facet of our lives. Its uses range from very advanced studies in high-energy physics to checking your dividend report on the income tax. Our 7094 computer can add figures having 10 significant numbers at the rate of more than 200,000 times per second. It multiples at a rate of more than 50,000 per second. This is faster by many, many magnitudes than any of us could complete similar calculations using a slide rule or desk calculator.

In 1935, I explored the possibility of solving a heat conduction problem which required the solution of 1,408 differential equations. A few hours using a desk calculator convinced me that if I lived to be 100 and worked 8 hours per day, there was a possibility I might solve it. Two years ago Dr. Conte and I programmed the problem for the 7094 computer. In an elapsed running time of one minute and 14 seconds, the differential equations were solved.

Recently a friend sent me an interesting sign used in a New York subway advertising evening school programs. It read,

"Are you educating yourself for a higher skilled job? If not, the computer will take your present job in five years."

5. The Immense Increase in Scientific and Technological Information and the Use of the Data Are Awe-Inspiring.

In order to illustrate the awe-inspiring speed of scientific and technological developments, I would like to briefly look at some points of the past and the future[5]:

1946

1. The U. S. Army Signal Corps personnel were successful in bouncing a radar beam off the surface of the moon. Today we receive telemetered electrical signals from satellites as a routine operation.
2. Through extensive research, engineers and scientists of the University of Pennsylvania unveiled a general-purpose electronic computer capable of adding sets of numbers in 1/5000 of a second or 5000 additions a second. Modern computers perform these operations at rates of over 200,000 additions per second of 10-digit numbers.
3. Admiral H. G. Bowen predicted that submarines of the future would be powered by atomic reactors. Admiral Rickover successfully developed the atomic submarine. Now United States and Russian atomic underwater subs are in operation in all of the oceans of the world.
4. On July 3, the bill for the formation of the National Science Foundation passed the Senate by a vote of 48–18. The resulting Foundation has had an enormous impact on engineering and scientific research.
5. The development of the high speed Bell XS-1 was begun in competition with the British Gloster Meteor which reached a speed of 606 mph. Today this is a slow speed in comparison to satellites traveling at 17,000 mph.
6. To study the particles of matter, the University of California constructed a cyclotron, which produced a beam having an energy of 15 million electron volts. Today the Atomic Energy Commission is building a 200 billion electron volt particle accelerator.
7. The now commonplace items, vitamin A and penicillin, were first synthesized.

1956

1. The United States announced that the first U. S. satellite would orbit the earth. This was after the first Russian satellite. Since then, many, many satellites and space ships have circled the earth.
2. The X-2 reached a speed of 2,100 mph and an altitude of 126,000 ft before it crashed.
3. Congress appropriated a record of 180 million dollars for the National Institute of Health. Great emphasis was and is now being placed on medical research.

A Brief Look at What Lies Ahead

1. The Ocean Floor—a Horn of Plenty.

[6]The ocean floor is a mineral "horn of plenty;" some minerals simply lie on the ocean floor in chunks. Manganese nodules have been found which contain about 50 percent manganese, 27 percent iron, and 2 percent copper, cobalt, molybdemum

[5] Reference: Tomorrow Through Research, Southwest Research Institute, Summer 1965.
[6] Reference: Exploring the Sea, A. Spilhaus, Ind. Res., March 1966.

and nickel. A South African company dredges 700 tons of diamond gravel daily from the ocean floor. The yield is 5 carats per ton and most are gem-quality stones. Compare this with land mining, which produces 1 carat per ton of diamond-bearing ore.

2. The Energy of The Waves.

We have only begun to study the possibilities of harnessing the power of the ocean tides, waves, and the thermal energy present due to the temperature gradients between the surface water and those at greater depths. These sources of power must be used to conserve our coal, petroleum, and gas resources.

3. Biologically Active Materials.

The different biologically active materials which will come from the sea staggers the strongest of imaginations. As of now, 1 percent of all sea organisms—known to be biologically active—have been studied. Results from this minute portion suggest unbelievable findings. For example[7]: Tetrodotosin is one of the most powerful pain killers known. It is extracted from puffer fish poison which is thousands of times more potent than existing war gasses. The greatly diluted drug eliminates pain that even narcotics cannot dull. Holothurin, isolated from the toxic secretions of sea cucumbers, may have a marked effect on cancer. Cancerous mice injected with this drug lived out normal life spans, while a control group died within two weeks. This material repels sharks and also retards coagulation of the blood.

How long it will be before doctors begin using marine drugs can only be predicted by the country's pharmaceutical companies. In the highly competitive pharmaceutical trade, details of any progress with new drugs are guarded like a formula for turning graphite into diamonds at atmospheric pressure and room temperature.

4. New Panama Canal.

In the not too distant future a new canal will greatly supplement the Panama Canal.[8] Two sea level routes are now being considered. Route 17 is 44 miles long and lies in eastern Panama. Route 25 is approximately 93 miles long and crosses the northwestern corner of Colombia. Excavation of the selected route will be accomplished by nuclear devices, which will constitute a major peacetime use of nuclear energy. If Route 17 is selected, 294 nuclear devices will be required. Excavation through the Continental Divide will require a detonation equivalent to 35 megatons. There are many engineering design problems yet to be solved before this project becomes a reality.

5. Learning Experiences.

A startling experiment was recently conducted by two University of California scientists, which may have a profound effect on learning. They trained a group of rats to scamper to a food cup at the sound of a click. Then they isolated a certain chemical in the trained rats' brains and injected it into the brains of other untrained rats. Then they sounded the click again; on hearing the noise some of the untrained rats dashed for the food bowls. The odds against just that number of rats rushing to the bowl at random was placed at 1,000 to 1. The conclusion is that the rats had learned from the injected chemical. I present this idea for you to dream about, as the possible consequences are unbelievable.

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[7] Reference: Drugs from the Sea, *News Front*, Oct. 1965.
[8] Reference: Nuclear Excavation, *Industrial Research*, January 1966.

Let us suppose that the technique may be applied to man as well as to rats. A young automobile mechanic, who had long desired to become an accountant, could go to a special clinic and take "accounting injections" and thereby learn to be an accountant in a relatively short period of time. I can feel the reaction in many of your minds that such a thing is ridiculous. Don't be too sure! If I had asked you 15 years ago if man would be able to orbit the earth in a space vehicle and walk in outer space, I think I know what your answer would have been.

6. Synthetic Meat.

"Synthetic meat from fully automated meat factories will be a scientific wonder of the not-too-far-distant future."

It amounts to growing meat in vats rather than on meat animals. The "starter" material is animal—the non-edible portions of slaughtered cattle, swine, or sheep.

The material is broken down chemically into cells. These cells are induced to multiply in a nutrient culture "soup" and to revert to protein-rich meat cells in the process. The "harvest" is meat.

Dr. Arthur Karler of the research and technical division of Wilson & Co., Chicago, told his fellow chemists the technology was so far advanced it now can produce not mere chemical variants of meat cells but "truly reconstituted meat proteins."

II. How Do We Design An Educational Program in Engineering for Tomorrow?

In January of this year we completed a five-year study of engineering education known as the Goals Study.[9] This has been a very interesting research project but a very difficult one.

Engineering is not a unified profession but a heterogeneous mixture of groups held together by somewhat similar educational experiences. There is no unified position regarding engineering education.

At this time I would like to point out some of the difficulties of interpreting the results from the institutional study committees and the industrial surveys by means of several examples.

Fig. 1 shows the institutional study committee results relating to the future technical role of engineering graduates. How would you interpret these data?

This is an example of data very difficult to analyze.

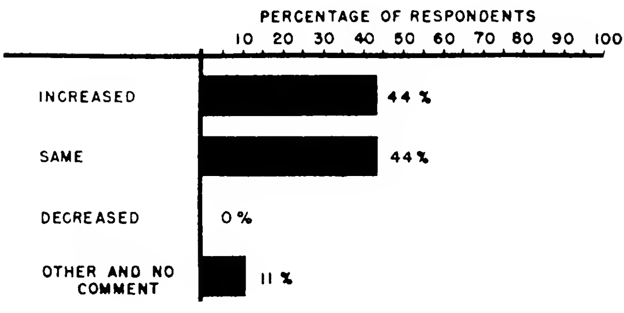


Fig. 1—Role of engineering graduates—technical role.

[9] Final report, Goals of Engineering Education, *Journal of Engineering Education*, Jan. 1968.

On the other hand there were examples of data showing decisive opinions. An example will be presented.

It is generally recognized that the engineer of the future—regardless of his special interests—should be provided with a fuller and richer understanding of the social and economic forces that will influence and be influenced by his technology. Expanded responsibilities of engineering are recognized by many engineering educators. Responding to inquiries about the future role of engineering graduates, educators from 156 institutions placed great stress on the growing social role of the engineer. (Fig. 2)

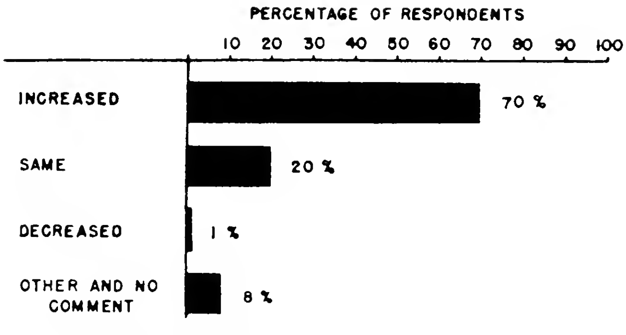


Fig. 2—Social role of engineering graduates.

The great variance in views of industries is clearly shown in Fig. 3. What would be your conclusion regarding the views of management as to the importance of high grades in college, and work experience in deciding on the hiring of a new engineering graduate?

Fig. 4 shows the attitude of industry regarding encouragement and reward for advanced work.

Fig. 5 shows the views of management regarding the most desired type of curricula which would best meet the needs of their respective organization.

What do these results mean?

After extensive study and analysis of the available data, study of the literature, interviews, and feedback from many sources, the Goals Committee reached the conclusion that five years of formal education for professional engineers will be needed in the next decade.

Based upon forecasts, observations, and objectives for the future, many of us feel that the era for educating a truly professional engineer in a four-year program for a lifelong career is coming to a close.

The Goals of Engineering Education Study Committee suggested that we adopt the following terminology for the future:

1. Undergraduate Education.

Undergraduate education covers the academic activities undertaken by students who work for credit toward a technician's certificate or bachelor's degree.

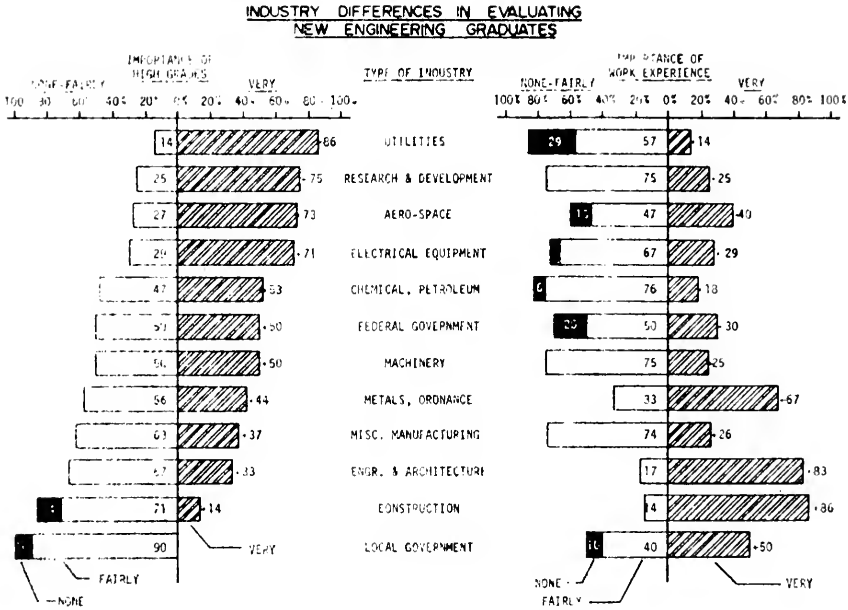


Fig. 3—The views of personnel representatives in various industries regarding the importance of high grades in college and work experience in deciding on the hiring of a new engineering graduate.

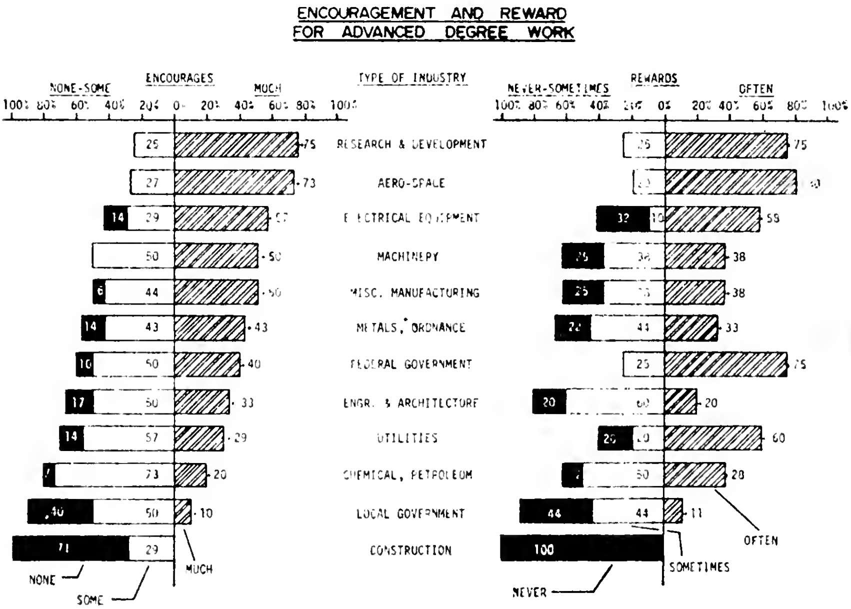


Fig. 4—The views of personnel representatives in various industries regarding the extent to which their respective organizations encourage and reward engineers who undertake advanced degree work.

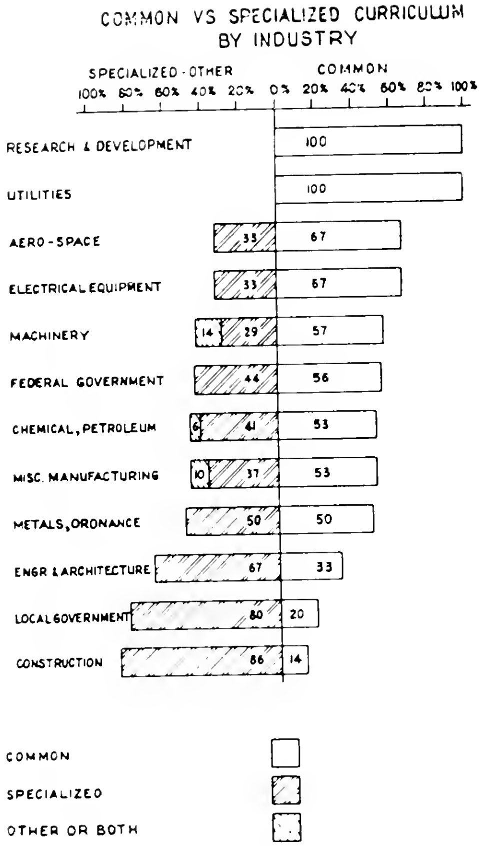


Fig. 5—The views of management representatives in various industries regarding the extent to which a specialized curriculum (ME, CE, etc.) versus a common curriculum with limited specialization would meet their organizational needs.

2. *Graduate Education.*

Graduate education covers the academic activities undertaken by students who work for credit toward post-baccalaureate degrees. This would include at most institutions the master's degree and the doctor's degree.

3. *Basic Education.*

Basic education is that which is expected for entry into a professional field. In architecture and pharmacy, this has normally been five years of work at the undergraduate level. In engineering, this has been the bachelor's degree in the past in most fields, although in some fields, notably sanitary engineering and nuclear engineering, this has been the master's degree and in engineering teaching it has been in recent years the doctor's degree.

4. Advanced Education.

Advanced education is education pursued by the student following his basic education. It is undertaken optionally. In medicine this would run from two to seven years depending on the specialty.

These four concepts are shown schematically in Fig. 6 for engineering education.

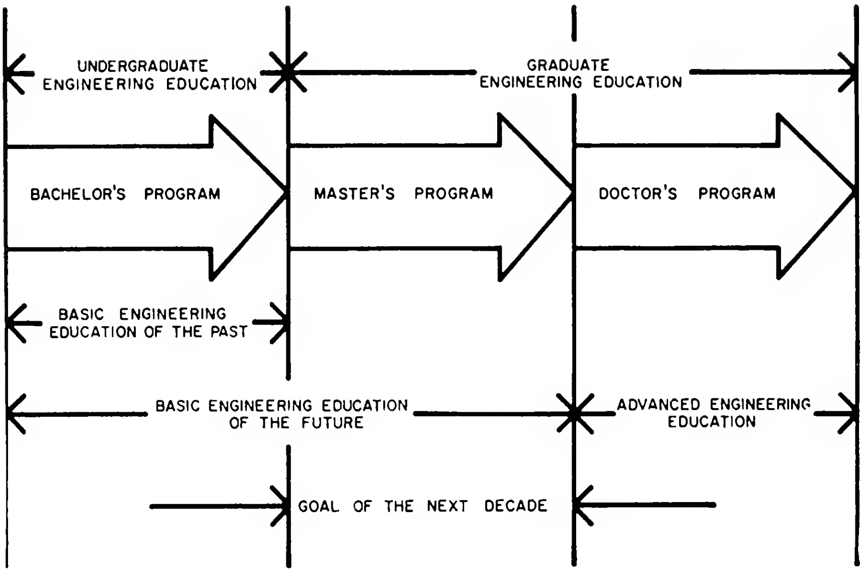


Fig. 6—Undergraduate and graduate engineering education versus basic and advanced engineering education.

We recommend that during the next decade basic engineering education for the professional engineer of the future be extended to include at least one year of graduate level education leading to the master's degree.

We recommend that the engineering profession and engineering educators recognize the inevitability of increased graduate level education in the future and take steps to provide the opportunity for at least one year of graduate study for those who expect to pursue professional engineering work and who will complete their basic education during the coming decade.

The two most important fundamental educational concepts to be included in the design of the programs of the future are: (1) education is a self-discipline, and (2) education must be a lifelong experience.

1. Education is a Self-Discipline.

The most important function of the teacher is to develop an atmosphere which is conducive to learning and stimulates the student's thirst for knowledge.

This may be dramatically illustrated by the actual description given by Helen Keller as to when and how the seed was sown by her great inspirational teacher, Anne Sullivan, that learning is a self-discipline. The incident I will describe happened approximately two weeks after Anne Sullivan became Helen Keller's teacher.[10]

[10] Reference, Great Teachers, Houston Peterson, Rutgers University Press.

"One day while I was playing with my new doll, Miss Sullivan put my big rag doll into my lap, spelled 'd-o-l-l-' and tried to make me understand that 'd-o-l-l' applied to both. Earlier in the day we had a tussle over the words 'm-u-g' is mug and that 'w-a-t-e-r' is water, but I was persistent in confounding the two. In despair she had dropped the subject for the time, only to renew it at the first opportunity. I became impatient at her repeated attempts and, seizing the new doll, I dashed it upon the floor. I was keenly delighted when I felt the fragments of the broken doll at my feet. Neither sorrow nor regret followed my passionate outburst. I had not loved the doll. In the still, dark world in which I lived there was no strong sentiment or tenderness. I felt my teacher sweep the fragments to one side of the hearth, and I had a sense of satisfaction that the cause of my discomfort was removed. She brought me my hat, and I knew I was going out into the warm sunshine. This thought, if a wordless sensation may be called a thought, made me hop and skip with pleasure.

"We walked down the path to the well house, attracted by the fragrance of the honeysuckle with which it was covered. Someone, was drawing water and my teacher placed my hand under the spout. As the cool stream gushed over one hand she spelled into the other the word *water,* first slowly, then rapidly. I stood still, my whole attention fixed upon the motions of her fingers. Suddenly I felt a misty sensation as of something forgotten—a thrill of returning thought and somehow the mystery of language was revealed to me. I knew then that 'w-a-t-e-r' meant the wonderful cool something that was flowing over my hand. That living word awakened my soul, gave it light, hope, joy, set it free! There were barriers still, it is true, but barriers that could in time be swept away."

Education as a self-discipline was accepted by Miss Keller.

2. *Education Must Be a Lifelong Process.*

[11]The four- or five-year college program is just beginning, since the average person spends about 40 years in his life carrer. The ratio of formal education to life-long is 4–40.

During the period of from one to approximately five years after commencement, young men often feel that their program of study should have included much more in the way of practical courses such as drafting, skill in programming, and so on. With a foundation of this type, they feel they could have started off immediately solving the day-by-day problems confronting them in industry.

The second group consists of those who have been out of college 5 to 15 years. These graduates feel that they should have had many more courses in mathematics, physics, chemistry, and the engineering sciences, as they need this type of information for solution of their difficult engineering problems.

The third group, having been out of school between 15 and 25 years, have become engaged in management and administration. In expressing their opinions they feel that they should have been given many courses in organization, public speaking, labor relations, finance, life insurance, retirement programs, budgeting, stocks and bonds, and investments.

The fourth group consists of those who have been away from college for approximately 25 years or more. Those in this class who return appear very disappointed that few of their courses were devoted to the fine arts, music, literature, drama, and foreign cultures. These are the areas in which they feel deficient when talking to their contemporaries, and when traveling.

It is obvious to all of us that it would not be possible for an engineering student to acquire, in a four- or five-year program, a knowledge of present-day

[11] Reference: The "Four Ages" of the Engineer, G. A. Hawkins, Engineers Joint Council, 1966.

practice, a strong foundation in the physical and engineering sciences, a broad education for management, and an appreciation for the arts, literature, and music.

Throughout my career as an educator, I have strongly advocated introducing one course in the sophomore year in which the student could gain credit only by self-study and passing a comprehensive examination as a means of helping him prepare for the future. I have suggested that this course should be followed by similar courses in the junior and senior year. So far, my words have fallen on deaf ears, since little progress has been made on this important area.

No colleague of mine has ever been able to give a sound reason why students should not be expected to study on their own. If we really believe in "lifelong learning," how are we, as educators, going to stimulate the student to develop self-study habits before graduation?

III. Continuing Education

Engineering schools must recognize more fully the place of continuing studies as a distinct category in the spectrum of engineering education. They must provide additional leadership in the planning and offering programs of continuing studies as a normal institutional activity. The engineering schools must cooperate to a greater extent with industry, government, and the engineering societies in programs of continuing engineering studies. In order to maximize the total effort, employers of engineers must facilitate in every possible way employee participation in programs of continuing studies.

We feel that engineering colleges should:

1. Establish and maintain high-quality, part-time, advanced-degree programs for on-campus study by employees of nearby industry and government agencies.
2. Devise new techniques and arrangements for extending high-quality, advanced-degree education to engineering graduates employed at locations remote from established campuses.

IV. Conclusion

In conclusion, we should develop in the basic engineering program of study situations where the student finally accepts the concepts that education is (1) a self-discipline, and (2) a lifelong experience. The employers of engineers should assume the responsibility of keeping them current by providing learning experiences. In education, we attempt to keep the faculty up to date by sabbatical leaves, industrial leaves, seminars, short courses, conferences, visiting professors and lecturers, etc.

There will be some who feel that their college or university commencement is not the beginning of their professional experiences and, hence, will not put forth any effort to expand their knowledge as they grow older. They will soon find themselves on the sidelines contributing very little to the main thrust of our progress, and will eventually become chronic complainers.

Some years ago, Dean Emeritus A. A. Potter of Purdue University was asked to speak before a large group of engineers from industry on the importance of continuing education. In closing, I would like to give you his final statement to the audience.

"Always remember the only differences between a grave and a rut are in dimensions and outlets."

(Applause)

Chairman Beeder: Thank you, Dr. Hawkins, for your very interesting and thoughtful talk here today. It is an honor to have you with us.

Mr. Chairman, this concludes the report of Committee 24.

Vice President Wilson: Thank you, Mr. Beeder, and your committee, for your report and efforts on behalf of the Association this past year. Your area of responsibility is most important to our profession and the railroad industry.

Dr. Hawkins, we are pleased you could be with us today and very much appreciation your discussion on the goals of engineering education. The philosophy embodied in the Goals report certainly is different than that prevalent when many of us were obtaining our education in engineering. Again, Dr. Hawkins, thank you for your efforts on behalf of our Association.

Mr. Beeder, your committee is excused with the thanks of the Association.

Vice President Wilson (continuing): This completes our morning session, but before I recess the meeting for the Annual Luncheon, I would like to remind you that the afternoon session will reconvene here in this room very shortly after the Luncheon is over. The first committee reporting, 14—Yards and Terminals, will present an outstanding and timely special feature, certainly one that will particularly interest the men on our structural committees. It will show the problems surmounted by the Bethlehem Steel Corporation while reconstructing Penn Station in New York.

The meeting is now recessed for the Annual Luncheon down the hall in the Grand Ballroom. Please assemble there as quickly as possible.

(The meeting recessed at 11:50 o'clock.)

Annual Luncheon, March 20, 1968

(The Annual Luncheon of the Association was held in the Grand Ballroom beginning at 12:00 noon. At the main speaker's table were seated the officers of the Association, several past presidents, and a number of special guests. At a long table immediately on front of the main speaker's table were seated the chairmen of the Association's 23 standing committees. Following the luncheon President Hutcheson spoke as follows:)

President Hutcheson: As President of the American Railway Engineering Association, I welcome you here to this our Annual Luncheon. I will now introduce those at the speaker's table and as their names are called, it is requested that they stand momentarily.

(The guests seated at the speaker's table were introduced.)

(Applause)

President Hutcheson: I will now introduce the chairmen of our 23 standing technical committees.

(The committee chairmen were introduced.)

(Applause)

President Hutcheson: During the course of our luncheon the executive secretary passed to me, from the chairman of our Tellers Committee, R. A. Pearson, assistant engineer of bridges, Illinois Central Railroad, the official report of the tellers giving the results of the 1968 election of officers.

I hold this report in my hand and I would like first to read the names of those you have selected to help direct the overall policies of our Association for the coming year. As I read their names, I would appreciate their standing in their place and remain standing until the last of the names on the list has been read. I know it will be difficult to refrain from applause as each name is read, but I would appreciate your doing so in the interest of conserving time.

(President Hutcheson read the names of the new officers and directors.)

(Applause)

President Hutcheson: These are the successful candidates for members of the Nominating Committee.

(The names were read.)

(Applause)

President Hutcheson: Just prior to the start of our Luncheon, President H. R. Miller of the Railway Engineering–Maintenance Suppliers Association, requested the privilege of the floor before the luncheon adjourned. Since we will adjourn immediately after our featured speaker finishes, I will now ask Mr. Miller to come to the microphone.

H. R. Miller: Members and guests of this 67th Annual Convention of the American Railway Engineering Association: The purpose of this request which has been so generously granted is to conduct an historic ceremony enjoyed by REMSA and previously by its two merged associations, the former National Railroad Appliance Association, and the Association of Track and Structures Suppliers. The membership of the supply organizations which now constitute REMSA has for 34 years had the pleasure of bestowing upon the outgoing AREA president a REMSA remembrance which carries with it the deep appreciation that our supplier membership wishes to extend to the AREA, through its president, for the cooperation and assistance which has been so gratefully received by us in past years.

I am honored to represent the Railway Engineering–Maintenance Suppliers Association this year. I am pleased that we can make our presentation again on the occasion of your Annual Luncheon. We feel that the AREA and REMSA memberships would both be participating.

I am pleased to read the inscription printed on this plaque:

"Mr. Thomas B. Hutcheson, President, American Railway Engineering Association, 1967–1968."

Mr. Hutcheson, on behalf of the membership of our Association, this silver plaque is presented to you with our gratitude for the increased liaison you have effected between our two Associations. This plaque, we hope, will also serve as a reminder to you of the personal cooperation we have enjoyed with you through the past 12 months. Thank you very much.

(The plaque was presented to President Hutcheson.)

(Applause)

President Hutcheson: Mr. Miller, I am deeply appreciative that your Association has seen fit that I have such a lovely reminder of a challenging, interesting and instructive year. I thank you.

At this time I would like to present a member of this Association since 1946, a former chairman of Committee 14, a past director of your Association, the son of a former president of this Association, an outstanding railroad engineer and operating man, my good friend, and my vice president, David C. Hastings, vice president of transportation and maintenance, Seaboard Coast Line Railroad, who will introduce our luncheon speaker. (Applause)

D. C. Hastings: Mr. President, honored guests, Members of the Association: Little did I realize 22 years ago when I sat down there for the first Annual Luncheon of AREA that I attended after I had become a member, that I would have the privilege and honor that Tom Hutcheson has bestowed upon me today. You know, in introducing a speaker, you can say too much, and you can say too little. The hour is already late. I know what his schedule is, and so as not to infringe on his time, I am going to be very brief; because Mr. Rice has done so many things, and he stands for so much, that I could take the full time allotted to him just in making the presentation.

Mr. Rice is a Virginian. He was born in Westmoreland County at Hague, Va.

He graduated from Virginia Polytechnic Institute in 1934 with a Bachelor of Science degree in civil engineering. He was later, in 1959, awarded an honorary LL.D. degree by Stetson University.

Following graduation, he entered the service of the Pennsylvania Railroad in its engineering and maintenance of way department, and when he was called to active duty with the United States Army in 1942 as first lieutenant, he was holding the position of track supervisor. He served overseas for three years in both the European and the Asiatic–Pacific theaters.

At the close of the war he had attained the rank of lieutenant colonel. Since that time he has been an active and a dedicated reserve officer. He is now a major general in the United States Army Reserve and holds a Mobilization Designation in the office of the Deputy Chief of Staff of Logistics, Department of the Army, Washington, D.C.

When Mr. Rice returned to civilian life in 1946 after the war, he went to work for the Richmond, Fredericksburg & Potomac Railroad Company as supervisor of track. He later became superintendent of the Potomac Yard, superintendent at Richmond, general superintendent, and on January 1, 1955, was elected president of the RF&P. He held that position until he was elected president of the Atlantic Coast Line Railroad in 1957.

On July 1, 1967, the long-awaited merger of the Atlantic Coast Line Railroad and the Seaboard Air Line Railroad was consummated and Mr. Rice was elected president of the new company. He is a director of the L&N and the RF&P, and various other organizations and subsidiary companies within the transportation industry. He is a director of several banks and a director of several large corporations, and has just recently been made a director of the United States Chamber of Commerce.

Mr. Rice is an Episcopalian, active in his church in Richmond, serves on the board of trustees of the Episcopalian Theological Seminary in Alexandria, Va. He is also a trustee of the Virginia Museum of Fine Arts.

Mr. Rice is a member of the Board of Visitors of his alma mater, VPI. He is a member of Tau Beta Pi, Omicron Delta Kappa, Rotary International, several national professional societies, and has been a member of AREA since 1947. Prior to his entry into the executive field, he was active in the affairs of Committee 16.

He is admired and respected for his rare executive ability in the railroad industry as a whole. He is loved by all of us on Seaboard Coast Line who have had the rare privilege and opportunity of being associated with him.

It gives me great pleasure to present to you the president, the chief executive officer, and a director of the new Seaboard Coast Line Railroad Company, Mr. W. Thomas Rice.

(Applause)

The Anatomy of a Merger

By W. THOMAS RICE

President and Chief Executive Officer, Seaboard Coast Line Railroad

W. Thomas Rice: Thank you, gentlemen. President Tom, Dave, honored guests, members of AREA and guests: It is very nice to be back home. I have been a member of this great organization for some time and I remember very well some of the things we used to do when we came to Chicago.

I am glad to see so many of you looking so bright-eyed today. I am pleased to come back here and talk to a group I have known for so long. I know there is a lot going on, and I won't keep you too long. I have a tight schedule myself.

I have told this story many times, and I think it is always appropriate, when you are in a position where it is applicable. And I think it is today, because after all, a man is not prevented from talking about his own company, and I feel like I am with a bunch of railroad engineering people. I saw one of my old bosses, Chet Henry, whom I have known so long. In fact, my first track supervisor's job was under him. I see another gentleman I served with overseas down here, and many more. So I am back with my old friends.

It seems, shortly after World War II when General Omar Bradley was head of the joint chiefs of staff, that he boarded an airplane. It is a true story. He boarded a plane at Washington dressed in civilian clothing, and happened to see an extraordinary lad dressed in the uniform of a private of the United States Army. And he was one of those young men who just wanted to know everything about everybody. And he looked at the general a little while, and pretty soon turned to him and said, "Hey, buddy, what's your racket?"

The old general looked at him in his kindly way and said, "Well, I am just the same as you are, I am in the Army of the United States."

Well the kid looked him over a little bit longer, and then said, "What are you, a master sergeant?"

He said, "No, I am a commissioned officer."

Well he waited a little bit, and then he said, "What are you, a major?"

The general, in telling this story later, said he knew it had to come out. This kid was just one of those kind who didn't shut up.

He said, "Son, I am General of the Armies, Omar N. Bradley, a five-star general, Chairman of the Joint Chiefs of Staff."

He said the kid looked him right in the eye and he didn't even blink, and said, "General, you've got a big job, don't louse it up." (Laughter)

Well I can appreciate that because I feel I am in the same position.

But seriously, a few years ago, one of the best sellers of that time, I am sure your wives read it, was a book called, "Anatomy of a Murder," and I might paraphrase that into "Anatomy of a Merger," because unless you have been through one of these things, and you gentlemen from the Penn Central know whereof I speak, a little insight as to what it is all about might be of interest. Not that we know all the answers, but we do know a lot of the heartaches that go with it.

Back in 1958, officers of the then Seaboard Air Line and the Atlantic Coast Line, sat down together, and we began talking about our problems. These roads ran side by side through the Southeast, and had some joint facilities. And finally in this conversation, though we never knew which one said it first, someone said, "Why don't we try to merge these two railroads?" The more we talked about it, the more sense it made. We finally decided to go to our individual boards of directors, and see what they thought.

They thought it was a pretty good idea, and we decided to employ consultants in the late winter of 1959 to look into the feasibility, engineeringwise. We got Wyer Dick and Associates, and a couple of other companies to come down and look us over and see if these two railroads could merge in the public interest.

Well they came up with a report in the spring of 1960 that indicated that it was very much in the public interest, and also in the interest of the owners, that these two properties merge. We then called meetings of our stockholders, and in August of 1960, the stockholders approved the merger by a tremendous vote.

So we immediately filed with the Interstate Commerce Commission, and thought we would have the merger consummated in about 30 days. You know, you can always be optimistic at first. But the commission appointed an examiner, and hearings were started. We had hearings twice in Richmond, twice in Washington, at Tampa, Savannah, Miami, and other places I don't remember. The record covers thousands of pages, replete with evidence in favor of the merger, with a few minor exceptions. The shippers were overwhelmingly for it; so were the legislators, the civic clubs, governors, utility commissions, you name it. Everybody was in favor of it except two or three of my associates in the railroad industry, the labor unions and the Department of Justice. So the record was complete. The last hearing before the examiner was held in late spring of 1961. We then thought, well boy, now we have got it made. We have the records, we have everything filed, it is bound to go through.

Then we sat on our hands and thought we would get at least a report from the examiner in 60 days. But how stupid could we be? We waited until a year from the next November. It was now November 1962. This was over two years after the owners had approved it.

After that we had to go before the Commission, the entire Commission, because this was a bell ringer case. We had a hearing before them finally in the spring of 1963. Finally one day, a cold day I never shall forget (I was on the first tee of the golf course, getting ready to play golf with some customers, you understand), somebody came running out and called me to the telephone. The 13th of December 1963, the Interstate Commerce Commission by a majority of two votes had approved our merger.

Then we thought we had it. Boy, it is all over now. We would go ahead and start setting up the organization and the vice presidents right quick.

Well, I don't know how many of you ever studied law, but if you didn't, you missed the boat. That is the most lucrative profession on the face of the earth. In a merger the lawyer has a picnic. They just make it go on and on and on until eternity. So the lawyers had to file and refile and the other side pressed for considerations, and many other things had to be taken care of. And finally in March of 1964, a federal court in Jacksonville enjoined us from putting the merger into effect. You understand, we had not done a thing. We were just doing a lot of thinking. We knew that this might happen, and we didn't want to scrap anything. The court set a hearing for mid-July. In mid-July, this was 1964, now, we had a hearing before the federal court in Jacksonville consisting of two circuit judges and one federal judge, and they came up with a decision about the spring of 1965, and said the merger could not go through, that the Interstate Commerce Commission had not properly considered the Anti-Trust provisions of the Clayton Act.

We were just completely frustrated, as you can imagine. Here we had been sitting on our hands all this time. Here it was late 1965. We were still trying to get each other's business and smile at each other when we met, and still trying to do all these things that you have to do to be good friends and still keen competitors.

For five long years we had waited, and then they said, you can't do it. We got a lot of free advice from our associates who had also tried to merge, as to whether we should go back to the Interstate Commerce Commission or the Supreme Court. Everybody had their own idea as to what we should do.

Finally we took the advice of our own counsel and went to the Supreme Court of the United States. And believe it or not, they remanded the case back to the district court in Jacksonville saying you erred in your judgment to refuse this merger. Look at it again because the evidence presented in two years supports it.

We felt a little bit better after that. We had to go back to the federal court at Jacksonville. It had gotten to be the spring of 1966, and we replead the case. At that time they came up with a perfectly wonderful decision, which, according to Art Castle, couldn't have been better if we had written it ourselves.

Then the opponents took it back to the Supreme Court to get it set aside, but finally in April of 1967, almost seven years after the owners of the property approved it, almost eight-and-a-half years since the idea was born in the minds of two persons, we received authority to go ahead and put the two properties together.

I tell you, when it happens, it scares you nearly to death. You have worked on this thing so long that you have worn out all your plans, and therefore you have to update them; but you don't exactly know where to begin, because a lot of the people who started this merger business are dead and some of them have retired.

We had made up a slate of officers back in the early 1960's because when the examiner recommended approval, we thought, boy, it is going through right now. But when the merger was finally approved, a lot of those people weren't even around any more.

When we got the decision, we sat down with the lawyers to try to put it together and decided to wait until July so we could comply with all the ICC requirements. We then had to come up with a slate of officers, department heads, what their departments would be, and the thousand and one details that go into putting together two railroads. You fellows who are getting ready to do it: I can't give you any advice except to say it takes a lot of doing, because you know you are going to have two people for every job, and somebody is going to come up No. 1, and somebody is going to come up No. 2. You just can't help it. It is bound to be. Try as you may, you are going to end up that way. And of course it isn't always a happy situation.

And then you have to locate. You know, we promised so many things about where we would have headquarters, and where we couldn't have headquarters, and about who would move and where. You have to keep people, and relocate your railroad headquarters in connection with these commitments. Your personnel changes. You have to move a lot of people. Everybody is on edge. Everybody is wondering, what happens to me? You gentlemen from the Penn Central know exactly what I am talking about. Those few days before the merger, you don't talk straight, you don't think straight. You wonder, what do I get? Have I still got a job? Most of you know you will still have a job, but it is a question of getting it set up and where you are going. Your division heads wonder; we had plans, Dave had plans, and his counterpart on the Seaboard had plans as to where the division headquarters would be. Of course, change in operations, change in volumes of traffic, office management, that is something you have to redo.

You have to think about every little thing. Can you imagine two box cars with the same number going into the computer? Two locomotives with the same number on a train order? That is something you have to think through. No two railroads are the same. The jumper cables wouldn't work between the locomotives on the Seaboard and the Coast Line. The track maintenance was not the same. That had to be rectified. But we tried to do this by getting the best of both, and use that as a standard.

You have to figure out your public relations. Those are some of the things we are learning from the Penn Central. Those are the kinds of things that have to be selected—your advertising program to tell the public what you are doing. Of course, everyone on every other railroad will tell you what to do and how to do it. And naturally, you have got to tell the public what you are going to do this time because it is something brand new, and you want to keep them informed.

Then on July 1, 1967, we had a board meeting, and I tell you, that was a board meeting. I never saw so many people in my life. It looked like there were as many as are in this room. We had 26 members of the new board. Of course, you know your old board, but you don't know who these new gentlemen are, and you look at them with a little bit of suspicion, and wonder how you will get along with them, and how they will perform. Well, of course, it works out very beautifully.

Then you set up a new staff, and you begin to think that you have a bull by the tail. We have two of each thing, two big properties, double the equipment, double the mileage, double the employes, and double the payroll, because of the guarantees that go in. Men who had fought like cats and dogs for years to try to get business away from each other, all of a sudden were sharing the same office, and that is quite an experience. The beauty of it is, though, it is amazing how things begin to fall into place. It is a most wonderful experience to see people who have fought each other for years all of a sudden begin to realize that each is a pretty good Joe after all, and they begin to work together. And it is a heart-warming experience, a very interesting one, a very meaningful one.

But I will say this, the big problem in any merger, of course, is to get the total job done, and you don't get it done until you merge your labor contracts. Implementing agreements are fine as far as they go, but they don't go very far, and until you can get all your contracts merged into one for each craft, gentlemen, you do not, and I repeat, you do not have a merger.

Today, all of our crafts have been merged with the exception of three. Until we can get those three completed, we will not do the job that is contemplated on the part of the merged company.

A typical example is our transfer crew taking a cut across the city where we have a yard of both properties, taking a cut across one yard to the other and going back again. Right behind them is the other transfer crew going to the other yard and then back again, pouring money down the drain. The stockholders don't understand that. To them that is just a lot of poppycock. They expect you to have the money tree in the backyard the minute the merger goes in. And as far as I am concerned, those first days are rugged. You not only don't have the money tree, but you need one to pay your out-of-pocket costs. Building new tracks, building new connections, planning everything to fit into the plan of merger from the standpoint of the engine numbers to the emblem on the side of cars in the freight station. I tell you, that is a big thing just to change the name.

I will pass over a few things because I want to bring this to a quick end; to say it is a thrilling experience, yes, there is nothing like it. I will guarantee to you, until you go through it, you will never know what it is like, to see what can be done, and to see the gradual unfolding, the potential of these mergers of the railroads in this country, and in the final analysis that is what we must have.

I have a couple of things I want to say to you, gentlemen, as engineers. What we need in this industry today, in my humble opinion, more than anything else, is unity—not only unity from the standpoint of freight rates and unity from the standpoint of engineering standards. We need unity in labor relations, in public relations, in our position on everything we do. The lack of unity in our industry has been a most disturbing and frustrating thing, and don't kid yourselves, redounds to our disfavor time and time again. This has been demonstrated so many times, I could stand here and talk about it for an hour.

This applies to you, gentlemen, and is the reason I bring it up. Certain railroads set a limit on the weight on a four-wheel truck, a limit prescribed by you in one of your committees and approved by the AAR. Is that the standard of the American railroads? No. A few real energetic, bright-eyd, traffic people decided they would like to get more business, and they will go to any means. And those of you who come from railroads who have to face that, know whereof I speak. We used to say in engineering and in operations, we tried to live down what the traffic people committed us to. Well I know that you know that the light sections of rail that we have on a lot of our railroads won't take these heavy wheel loads and take them safely. And the lack of unity on this question isn't good, particularly when we have people introducing bills into Congress to make us more regulated safetywise. We can't even get together on how great a wheel load rail can stand. Every one of you who remembers your courses in strength of materials and elastic limits knows perfectly well there is a limit you can't exceed in loading down this old rail, particularly if you have some soft ties under the joint. And I dare say many of us have exceeded this limit, or we wouldn't be in business.

One of the challenges we all have is our lack of unity. All we need to do is just have a few years of bad experiences, any type of experience, and there are gentlemen in Washington who will do their utmost to put somebody up there who will tell us how to maintain track, how to tamp ties, when to lay rail, and when to install ties. And gentlemen, that is not beyond the horizon. Don't kid yourself. We can't beat it down or regulate it if we don't do the right kind of job ourselves.

Yes, the challenge is a great one. The cost that the railroad industry has been subjected to in the past several months make it absolutely imperative we find other means of income. You gentlemen have done so much with your supply associates in the last 15 years. The methods now employed in maintaining rail structures is so different, so much more quicker, so much more economical than it was 15 years ago. There is just no comparison. Where we would be if you had not come up with these almost unbelievable machines that do so much work that used to require so many men to do?

But gentlemen, your job is not done. Keep on trying to find a better way to do the work we are now doing; the prices we are paying for labor makes it imperative. We must find ways and means of getting better material and building better machines, doing everything possible that will reduce our capital outlay and give a larger return on our investment.

Now I think I have talked about long enough. If I don't stop you will be reminded of the story about this man, one of a minority group, shall we say, who was walking down the street in one of our southern cities. He met a member of the opposite sex; they walked along and began talking. It wasn't long before they became fast friends. She invited him up to her apartment to see her etchings, and he viewed the etchings from one room to the other. Finally late in the evening he heard a key in the front door lock. And he turned to her and said, "What is that?"

She said, "Why that is probably my husband coming home."

He said, "Husband? Where is the back door?"

She said, "We don't have no back door in this apartment."

He said, "Well tell me quick, where would you like one?" (Laughter)

Well I am afraid I will have to take the back door. (Laughter)

(The audience arose and applauded.)

PRESIDENT HUTCHESON: Thank you, Mr. Rice. Gentlemen, you have had an insight into the dynamic leadership which Dave was talking to you about, which those of us on the Seaboard Coast Line enjoy. Mr. Rice, knowing how busy your days are, I want to express our appreciation and the appreciation of the Association for your taking time to attend our convention and for delivering this dynamic, interesting, and constructive talk.

Before adjourning this annual luncheon, I would like to remind you that our afternoon session will convene immediately in the Red Lacquer Room.

(The Luncheon recessed at 1:55 o'clock.)

Afternoon Session, March 20, 1968

(The meeting reconvened at 2:10 o'clock in the Red Lacquer Room, with President Hutcheson presiding.)

Discussion on Yards and Terminals

(For report, see Bulletin 609, pages 143–168)

PRESIDENT HUTCHESON: Gentlemen, the first report of this session will be presented by Committee 14—Yards and Terminals, the chairman of which is H. J. McNally, chief engineer, New York Improvements, Penn Central Company, New York. Mr. McNally is unable to be with us because of a "slipped disc," and I understand his problem.

The vice chairman of the committee, who is C. E. Stoecker, planning and construction engineer of the Louisville & Nashville Railroad, Louisville, Ky., will present the report.

Since the members of the committee are already on the platform, I will now turn this microphone over to Mr. Stoecker without further comment, except to remind you that your questions are welcome. If you have any, please state your name and railroad or other affiliation, and then fire away.

Mr. Stoecker, please proceed.

VICE CHAIRMAN STOECKER: Committee 14 had a very interesting year, and a fairly productive one as far as its reports are concerned. We had two interesting field trips; the first to the Taconite handling facilities in Duluth, Minn., and the second to the new Norfolk & Western yard at Belleville, Ohio. Both of these trips were very interesting and educational for the committee members. Our appreciation is expressed to all those individuals who helped make those trips possible.

Reports were made by the subcommittee on Revision of the Manual headed by Jerry Chabot, assistant contract engineer of the C&O–B&O.

John Dahlrot, supervisor of scales and weighing, of the L&N took over as subcommittee chairman for Buck Buchanan who died during the year. All of us will miss Buck, who did an outstanding job in handling the Scales Subcommittee work down through the years. I would also like to say thanks to John for taking on that chore and for the presentation of a very interesting report on Belt Conveyor Scales.

An interesting report describing the new Taconite handling facilities of Great Northern at Duluth was prepared by Charles Intlekofer as subcommittee chairman. He is assistant chief engineer, Lines West, of the GN.

Jack Sutton, project manager of the CNR, headed the subcommittee which prepared a report on a unique hydraulically operated system which accelerates and brakes the movement of cars in the Tinsley Marshalling Yard near Sheffield, England.

Max Clark, division engineer of the Penn Central headed a subcommittee which prepared a report on "Expediting Passenger Handling in Stations and Terminals." This is a subject of current interest to many AREA members.

Basil Buterbaugh, principal engineer of the StL–SF headed a subcommittee which was to prepare a report on "Factors to be Considered in the Revision of a Manually Operated Yard to an Automatic Retarder Yard." This was not completed this year but should be ready prior to the next convention.

Vice Chairman Stoecker (continuing): This report was to be Harry McNally's last report as chairman of Committee 14. He has asked that I express his appreciation for the opportunity to serve as chairman, and to say thanks to the committee members for their help during his three-year term. He is, of course, also appreciative of the help from Secretary Hodgkins' and his staff and wishes to thank them also.

I will be taking over as chairman and Jerry Chabot of the C&O–B&O, will be vice chairman for the next three years. I guess Harry thought this would be a good time to break me in and get me started early.

Vice Chairman Stoecker (continuing): Committee 14 has a Special Feature to present to you this year. About 5 years ago Harry McNally spoke before an AREA Convention on the subject of the development of the air rights over Pennsylvania Station, New York, outlining what they had in mind to do. At that time he indicated that if you would have him back in four years or so, he would report on how they finally accomplished the job.

In the meantime, Mr. McNally found a fellow who he thought could make a more interesting presentation of at least one phase of the work and who will speak to us today and show us some interesting slides on "The Fabricated Steel Erection Problems Incident to the Redevelopment of Pennsylvania Station in New York City." He is James A. Sterner, assistant district manager of erection, New York Erection District, Fabricated Steel Construction Department, Bethlehem Steel Corporation.

A better description of Mr. Sterner's job would be somewhat as follows:

He is responsible in seeing that Bethlehem makes a few dollars out of a job even though he had nothing to do in setting the price; he has no control over the shop production, and if the shop may have forgotten a piece which at the moment is holding up the erection of a couple of thousand tons of steel, he must see that delivery is made even though the New York City Police Department is outside saying that you must get those half-dozen trucks off the street; and the ironworkers are saying that we have to quit early today since the transit workers are threatening to strike. And he has to put up with such other happenings as: the owner will not let the concrete contractor pour a section of concrete until Monday, and it should be done today, which is the previous Wednesday, so that the ironworkers can work efficiently next week. He has, of course, other responsibilities.

Mr. Sterner is a graduate civil engineer from Lehigh University and has worked with Bethlehem Steel Corporation since his graduation.

He has erected some very interesting structures, including five major structures at the New York World's Fair. For those of you who were at the Fair, these structures were (1) the General Electric Pavilion, (2) the Bell Telephone "Flying Wing," (3) the United States Pavilion, (4) the Travellers Insurance Company Pavilion, and (5) the Observation Towers of the New York State Pavilion.

Previous to that work, one of his interesting jobs was the erection of the second deck to the George Washington Bridge—a really outstanding project built over water and under a bridge in constant service.

The project which, no doubt, gave him the most headaches was the Penn Station project and the erection of the steel for the new Madison Square Garden, the subject of his talk today. This work included the erection of a 404-ft-diameter cable roof structure, a first job of this size for him or his associates with Bethlehem Steel. It was a success, but not, of course, without encountering problems similar to those which arise, as all of us know, when we try to turn a bit of theoretical information into a practical application.

Gentlemen, James A. Sterner of Bethlehem Steel Corporation.

Steel Development at Pennsylvania Station, New York City

By J. A. STERNER

Assistant Manager, New York Erection District, Bethlehem Steel Corporation

Pennsylvania Station, New York City, a classic example of ancient architecture was built in the early 1900's patterned after the Roman Baths of Caracalla. For the past few years Pennsylvania Railroad (now part of the Penn Central Company) has been looking into various proposals to utilize the air space over this valuable piece of Manhattann real estate. After studying many proposals it was agreed by the Pennsylvania Railroad and the Madison Square Garden Corporation to build a new concept in sports arenas above Pennsylvania Station and in addition to redesign and modernize the station itself. The transformation from the old to the new required almost 30,000 tons of structural steel of all sizes, shapes, and strengths. This transformation could never have taken place without the utmost cooperation between the owners, architects, engineers, and contractors to insure that the 600 trains and the quarter of a million people using the station daily could do so without interruption and with complete safety.

Motive power at track level about 50 ft below the street consists of an 11,000-v a–c overhead catenary system and a 660-v d–c third rail system. Since the Pennsylvania Railroad would allow only two adjacent tracks out of the 22 in the station to be out of service at any one time during normal working hours, our operations had to be scheduled track by track to conform with this limitation. The new concrete foundations were also installed under these circumstances prior to structural steel work. In all stages of planning the safety of the station and its occupants was paramount. Temporary facilities were built for public safety both to protect the passengers as they used the station as well as the various concessions which remained in operation during the alterations. The erection of steel adjacent to public areas became commonplace as people in the station seemed to become completely blasé about the work around them and payed little attention to our operations.

The general scope of our work to redevelop the station consisted of the erection of new grillages and base plates at track level, new columns up through two existing floors of the station, and a complete new floor of structural steel at approximately street level. All of this steel, approximately 16,000 tons, was erected in the station area within the 400 by 800-ft city block. The new floor of steel had to be erected prior to the demolition and construction of the new buildings overhead. It also acted as a weather shield to protect the vital operating parts of the station below.

As in every contract where an existing structure is to be modified, the first step is the taking of field measurements to determine the exact location of the existing steel framework, because wherever possible the design engineer utilized it for additional loads and support for the new steel. These measurements along with the utilization of existing detailed drawings enabled us to produce a new set of over 2,000 working drawings for construction, including framing plans, details, and field work sheets. At each and every point where a new steel penetration had to be made, a clearance sketch was also prepared showing the relationship of all existing interferences to the final location of the new steel and also clearances required to allow us to erect the new steel. The 1,000 sketches thus prepared showed railroad signals and cable, catenary supports, electrical fixtures and conduits, concrete, drainage piping, and heating ducts, to mention a few, all of which had to be removed or relocated clear of the new steel location.

The double city block on which the existing station was built was divided into three demolition and construction phases. The central third or Phase I included the old ticket concourse and waiting rooms. The west third or Phase II included the existing main train concourse. Above these two areas will rise the New Madison Square Garden. Phase III or the east third covered the Long Island waiting rooms and in this area a new 30-story office building will rise. The construction area is bounded by 33rd St. on the north, 31st St. on the south, 7th Ave. on the east and 8th Ave. on the west.

Now let's discuss some of the problems we encountered to erect this new steel at Penn Station and how we solved them. At track level, as dictated by railroad clearances, we erected various types of grillages. Where new wide-flange columns were erected, both base plates and normal grillages are used. When the engineer elected to reinforce an existing column to enable it to carry additional loads by wrapping four new column angles around it, two distinct types of grillages were designed. On the columns within the platorm area, two large bridging plates were used. They were set in an upright position and tied together with diaphragms to span an existing footing, providing a bearing for the four new column angles. When columns which were located between two operating tracks were reinforced, an "A" frame type of grillage was used. Here two wide-flange beams act as legs to span the existing footing, with gusset plates tying them together at the top, which also act as a bearing area for the new column angles. A pair of 2- by 4-in steel bars hold the feet in position and take the horizontal load component of the legs. This type of grillage was used to keep within tight track clearances required by the Pennsylvania Railroad.

Most of the steel at track level was erected by a diesel powered railroad crane furnished by the Pennsylvania Railroad which was specially modified for this particular use. It had an 18½-ft-long boom with a capacity of 6 tons at a radius of 22 ft. The limitation is due to the presence of the overhead catenary system which provides only a 15½ ft clearance above top of rail. Existing fixtures, which could not be relocated, sometimes reduced this headroom even more.

Material for grillage and track area erection was loaded on flatcars at our Pottstown, Pa. fabricating shop in a precise, prearranged pattern which was dictated by a closely engineered erection sequence. These cars had certain length and width requirements set by the PRR for operation in the station. The cars were shipped to New York and held in a storage yard just west of the station until required, and were delivered to the work area by the railroad crane as it reported for work each morning.

Due to the capacity limit of 6 tons, we field assembled most of the grillage systems; however, there were a few extremely large grillages which could not be field assembled and which weighed much more than this limit. We therefore requested the railroad to furnish a 50-ton-capacity wrecking crane to erect these pieces, weighing up to 20 tons. Some of these grillages were erected as much as 8 to 10 ft below track level. The controlling factor for all this track level erection, of course, was use of tracks. As stated before, each track is equipped with a catenary and third rail electrical system; therefore, it was necessary to have both these systems de-energized during construction. Track usage was scheduled one week in advance so that coordination of all trades could be affected. The complexity becomes apparent when you consider that all new column locations had to be excavated and footings poured, demolition and preparation work for steel erection had to be completed, and the steel erected, welded, and bolted.

Where the existing columns were reinforced to carry additional loads, four new angles were placed around the existing column. These angles, as stated before, rested on the bearing surface of the various types of grillages at track level. The four angles were tied together every few feet with tie plates and were welded to the existing floorbeams for stability. Where the existing columns end, the four angles were topped off with a bearing plate, and a wide-flange section will continue the column upward. Typically at this point there is no bearing on the existing column, but in some isolated cases where the engineer wanted both the old and new columns to act together, we had to field mill both the old column and the four new angles to provide a satisfactory common bearing surface for the new columns above.

Where new wide-flange columns were to be erected on the common grid line with existing steel, an interference developed with the new column penetrating an existing beam in the floor. We solved these interference problems in two ways. First, through the use of two brackets on the new column erected below, we wedged and shimmed the existing beam from the column bracket. The existing beam was then cut to allow the next shaft of column to be erected and bolted to the column below. A shear plate was then welded to the column and the existing beam for load transfer, and the brackets were removed. In some cases where brackets were not feasible, we utilized various methods to shore or hang an existing beam so it could be cut prior to the new column erection. Again, after the new column was erected a welded shear plate transferred the load from the existing beam into the new column.

Since the new Madison Square Garden complex to be erected above was a circular structure, the problems of getting these columns down through a rectangular grid system of steel framing and a parallel track arrangement were many and varied. Because of such an incompatible arrangement various types of transfer girder systems were used to get the Madison Square Garden column loads into areas where they could be transferred to rock at track level either between tracks or in the platform areas. These transfer systems were placed at various levels to suit both physical placement and architectural limitations.

The erection of the floor steel for the central area or Phase I of the substructure started in the south carriage driveway with erection proceeding in a northerly direction. The existing steel framework was bared for the new connections and access holes for equipment were made into the station itself. The erection of this area outside the main waiting room was done by two 12½-ton-capacity hydraulic cranes working on the existing carriage driveway of the station. As work moved inside the main waiting room, which was cleared of all facilities and pedestrian traffic, it was decided to operate our erection equipment directly on the floor of the waiting room and ticket concourse. We practically covered the 230 by 400-ft with 6-in., 8-in. and 12-in. timbers to provide work areas in addition to crane and truck runways on the floor. Steel was delivered by trailer truck directly inside the station to the erection cranes. Special trailer loadings were dictated by floor load requirements and complicated erection procedures. Erecting a steel floor inside a building posed many problems, such as erection clearances, support of equipment, delivery of materials, and lack of storage space. The erection procedure was engineered to a precise piece-by-piece sequence to meet all these conditions.

The existing walls supporting the roof which had to remain in place during erection, divided the central area into smaller rooms, all of which received new steel. The steel in these areas was tied into the existing wall columns occasionally, but mainly it was self-supporting. After demolition of the walls these areas were tied together with small filler beams and diaphragms to form a continuous floor of steel over the entire site. There were many girders in this area which were erected by both hydraulic cranes; the heaviest weighed slightly over 20 tons.

As the work in the upper levels of the central area was progressing, we were also erecting the grillage under the main train concourse which was the west area or Phase II of the construction. Similar procedures that we used to erect the Phase I grillages were utilized here. Upstairs in the train concourse, however, procedures were much different than used before due to a few very important factors. The steel design called for much heavier girders in this area, up to 32 tons. The existing floor of the train concourse was a glass-block construction with very little load-carrying capacity, and all trains were loaded through the main gates located on this floor. Therefore this area could not be cleared of people. It was therefore decided that the erection equipment would operate on the new street level steel as it was

Erection of foundation steel and load transfer devices with 60-ton capacity truck cranes took place in a closely coordinated effort that enabled 250,000 people and 640 trains to pass safely and with minimum interference through Penn Station every day.

erected. Work started at the south or 31st St. end of the concourse and proceeded northward. Sixty-ton-capacity truck cranes were moved out on to the steel to erect the long girders which span the train concourse. The cranes operated with a 60-ft-long boom which just barely cleared the existing roof trusses. Steel was delivered directly to the crane with heavily loaded trailer trucks using the same timber runway upon which the truck crane operated. The girders that span the new train concourse are about 60 ft long and range in weight from 18 to 32 tons. The dominant feature of construction in this area is a huge truss which is about 275 ft long and 35 ft deep, running in a north-south direction slightly west of the center line of the building. The bottom chord of this truss supports the long girders which span the main concourse which will be covered with a metal deck and concrete floor at street level. The top chord of this truss will act as the middle support for eleven girders which will make up the main arena floor of the Madison Square Garden sports complex above. These girders will be over 270 ft long and will weigh about 260 tons each. More about these later.

The truss members are made from wide-flange column sections; all gusset plates are 2¾ in. thick. The truss was shop assembled and reamed to provide good field connections which were bolted with 1⅛-in. and 1¼-in.-diameter A 325 high-strength bolts. All field connections of new steel to new steel were accomplished with the use of high-strength bolts. All field connections of new steel to existing steel were welded, using AWS procedures, with about 50,000 lb of low-hydrogen E7018 series welding electrodes being used.

The erection of the east area or Phase III was accomplished by using different procedures and much different equipment. The grillages below at track level were handled in the same manner as before using the railroad crane and the wrecking crane for extremely heavy pieces. In this area, it was decided by the Pennsylvania Railroad to demolish most of the existing buildings prior to steel erection. This procedure allowed us to complete the substructure erection using a 115-ton-capacity stiff leg derrick traveler which started its erection pass at the south end of the building and proceeded northward. Material was delivered by trailer truck using a heavy timber runway along side the traveler. Since this area of substructure steel was utilized to support a 30-story office building, some of the girders were very heavy. The heaviest was over 80 tons although it was only 53 ft long. This traveler had the capability of erecting this 80-ton girder at a radius of 75 ft. As the traveler proceeded northward it left behind a grid of column stubs which were the starting points for the office building structural steel which was erected by another contractor. The east area or Phase III required over 7,000 tons of steel to modernize the station and provide foundations at street level.

Upon completion of the 8,500 tons of steel work in the central and west areas of the station, 48 pairs of column stubs arranged in a 404-ft-diameter circle were visible at street level. These are the roots on which the new garden will grow. As soon as the concrete floor at street level was poured in any area the demolition contractor moved in to start removing the existing station. As the demolition work continued in the extreme west end of the station we were already at work in the Central area erecting the superstructure portion of the complex which was to become the new Madison Square Garden.

Basically, Madison Square Garden is a circular building 425 ft in diameter and 150 ft tall. It will contain a main arena which will seat approximately 20,000 people under a cable-supported roof which offers no interference to sight lines from any seat in the house. The arena floor is approximately 45 ft above the street and is mainly supported by 11 continuous two-span girders which were erected by a 115-ton-capacity stiff-leg derrick traveler operating on the street level slab. The compression ring, 404 ft in diameter, is made up of 48 equal segments each about 26 ft long and weighing about 25 tons. These segments were erected by a 125-ton-capacity truck crane which operated on special steel mats laid on the new garden floor. This crane was equipped with a 175-ft boom plus a 30-ft jib and could erect 25 tons at a 50-ft operating radius. The crane was hoisted to its working position on the arena floor by one of the 70-ton-capacity guy derricks which was used to erect the east portion of the Madison Square Garden superstructure up to the arena floor. This crane placed the 25-ton compression ring sections 102 ft above the floor. All of the steel, including the inclined beams which will support the permanent seats, were erected as the crane made one pass around the structure. The garden also has four steel framed escalator towers, each containing 12 high-speed escalators running from street level to balcony level and which are designed to evacuate the entire 20,000-seat main arena in 22 minutes. The final closing section of compression ring was fitted into place with little difficulty, which was made possible by continuous

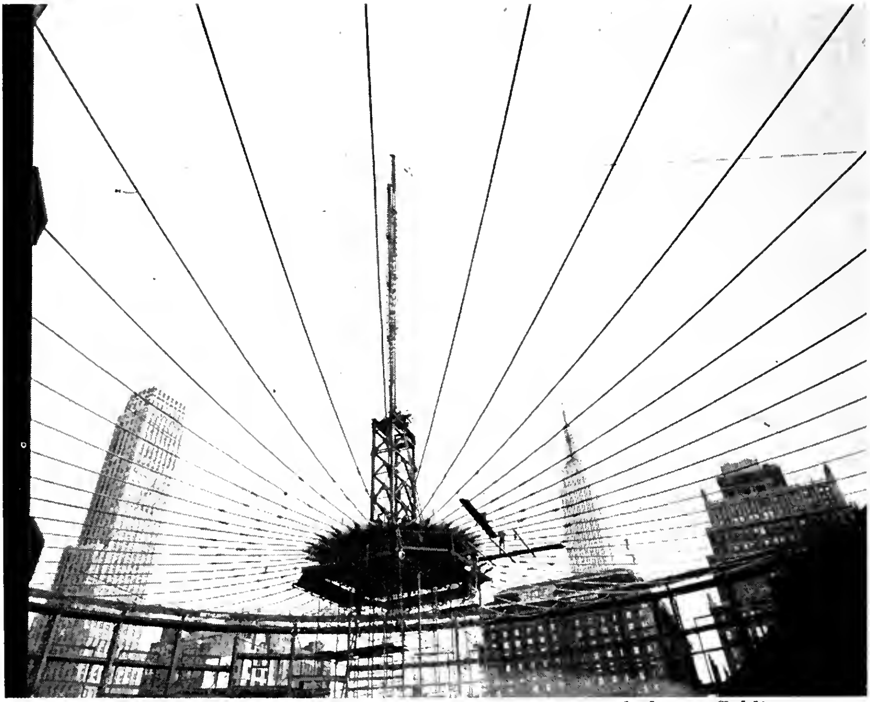
Constant control in erecting the compression ring assured that the closing piece would go in with no problems. Adjacent ring columns were jacked apart 1½ in., and closure was easily made.

and constant control on the position of the compression ring as each section was erected. Once the final piece was fitted in the compression ring, it was completely bolted together and was now ready to receive the roof cables.

The other component of the cable roof which had to be in place before cables were strung, was the 42-ft-diameter tension ring. It is a weldment of A 441 manganese vanadium steel weighing 102 tons. The tension ring was shipped to the job in four sections, and erected on a previously built falsework tower in position in the center of the main arena floor. The four sections were welded together under the protection of a canvas enclosure in a 7-day, continuous 24-hour around-the-clock welding operation. During this time we deposited over 2,000 lb of E7018 series welding electrodes. Ultrasonic inspection was performed by the owner during this operation.

As this welding was taking place, we were preparing the structure for the erection of the 48 main roof cables. They were delivered to the arena floor by trailer truck on wooden reels 10½ ft in diameter. Each cable is 3¾ in. in diameter, about 200 ft long and weighs about 3½ tons. It is composed of 271 hard-drawn wires arranged in 9 concentric layers. When the tension ring was 100 percent welded, we erected a guy derrick on top of it with a 110-ft mast and a 90-ft boom which was guyed to the arena floor by wire–rope guys. This derrick helped in the erection of the roof cables and a portion of the roof steel.

The erection of the roof cables was carried out in a carefully engineered sequence to minimize any unbalanced forces on the compression ring during partial



The tension ring and the erection derrick rested on a tubular scaffolding tower, which was set on a system of temporary timber cribbing on the arena floor. The forty-eight $3\frac{3}{4}$-in. diameter roof cables are ready to receive roof steel.

cable erection. Up on the compression ring we mounted an air hoist to furnish the power for hoisting the outboard end of the roof cable. The line was fed over a sheave bracket attached to the back of the compression ring, down through the hole in the compression ring girder, and over a roller boom to the arena floor. Here the line was attached to the socket at the compression end of the cable and pulled up over the boom, through the hole in the compression ring, and fastened to the outside with a large spanner nut. Once the outboard end of the cable was secured to the compression ring, the hook of the guy derrick dropped down and picked up a line attached to the inboard socket to hoist it up to the tension ring where it was attached to the tension ring with a 7-in.-diameter pin. This procedure was followed for all cables. When all 48 cables were erected, and before we could start erection of the roof steel, a system of polypropalene safety nets was stretched across the entire area below the roof cables. They were attached to a series of ¾-in-diameter ropes stretched completely across the arena and attached to the perimeter columns. Fifty-two such nets, 40 by 80 ft in size, were used for this purpose.

The erection of the roof steel from the center to a radius of 85 ft was accomplished by the center tower guy derrick lifting the material from the main arena floor below, where it was unloaded, sorted, and stacked by a hydraulic crane. The erection was done in a predetermined sequence to keep the loads balanced as equally as possible in all 48 cables. With the circular truss completed at 85 ft radius and 800 tons of roof steel erected, we planned to measure the tensions in all 48 cables. The cable tension measurements were taken by 60-ton center-hole pulling jacks attached to the cable socket on the outside of the compression ring. After two complete sets of readings and two complete adjustments, the cable tensions were equal in all 48 cables within a tolerance of plus or minus 2 kips.

While the cable adjustments were being made, we erected two opposing high-line erection systems capable of erecting the remainder of the roof steel. One end of the gut line was attached to the top of the guy derrick and the other to a movable anchorage bolted to the top of the compression ring. On this line rode a small trolley using a two-part lift line capable of erecting 6 tons. Two such systems were used opposite each other to erect the steel from the circular truss at the 85-ft radius point to the compression ring. Material was delivered to the arena floor and hoisted by the guy derrick and landed on the previously erected portion of the roof. From this point the steel was picked, trolleyed out on the gut line, and erected.

The problems of erecting the first permanent cable roof in the city of New York were many, but the end result certainly is one of functional and architectural beauty. The imaginative foresight of the Pennsylvania Railroad people in utilizing air rights to such a degree has provided sports fans of New York City with a magnificent new arena, plus an up-to-date, remodeled railroad station. The Penn Central Company should indeed be proud of its accomplishment. Thank you. (Applause)

Vice Chairman Stoecker: Jim, we want to thank you for a fine presentation.

I don't believe, Mr. President, there will be any time left for any questions, so that concludes the report of the committee.

President Hutcheson: Thank you, Mr. Stoecker, for the report of your committee, and for the efforts of all of you this last year.

Mr. Sterner, we greatly appreciate that most interesting discussion of the problems you encountered in the Penn Station project. Thank you for your efforts on our behalf.

Mr. Stoecker, as a symbol of your new authority and to assist you in conducting the meetings of your committee, I would like to present you with this chairman's gavel. The inscription reads:

"C. E. Stoecker, Chairman, AREA Committee 14, 1968–1970."

(The gavel was presented to Mr. Stoecker.)

Chairman Hutcheson: The Association is deeply appreciative of the efforts which Mr. McNally has exerted on its behalf during his period of chairmanship. From the past performances of both Mr. Stoecker and Mr. Chabot, we know that the work of the committee will continue in good hands.

Mr. Stoecker, your committee is now excused with the thanks of the Association.

Discussion on Buildings

(For report, see Bulletin 611, pages 385–387)

President Hutcheson: Gentlemen, the next committee to report this afternoon is Committee 6—Buildings. Will that committee please come to the platform? The chairman of this committee is W. C. Humphreys, architect, Penn Central Company, New York.

Mr. Humphreys, you may proceed with your presentation.

Chairman W. C. Humphreys: Mr. President, members of the Association and guests:

The members of Committee 6 in the selection and development of their subcommittee assignments are directing their attention to applying building construction techniques and design technology as they specifically relate to the railroad industry and the design of railroad facilities.

We will make a brief status report on three of the assignments which we feel may be of special interest to the Convention. These assignments are: Revision of the Manual, Fixed Facilities for Piggyback Terminals, and Computer Uses for Railway Building Design. Before giving these status report, however, I should like to introduce our other subcommittee chairmen:

R. J. Martens, general architect for the Union Pacific is chairman of Subcommittee 3—Design Criteria for Railway Office Planning.

Ike Forbes, engineer of buildings for the Illinois Central, is chairman of Subcommittee 4—Design Criteria for Railway Crew Facilities.

I would also like to introduce Tony Charvat, engineer of buildings, Rock Island Lines. Tony was chairman for our assignment on Ceiling Systems for Air Supply and Sound Control which was completed during 1967 and the report published in the January Bulletin.

Don Bessey, assistant architect for the Milwaukee Road, is our vice chairman and Omer Denz, also of the Milwaukee, is our secretary.

And now I would like to call on Walter Sturm, designer with the Elgin, Joliet & Eastern Railway, to give his status report on how we plan to revise our Manual material. Mr. Sturm.

Assignment 1—Revision of Manual

W. C. Sturm: Mr. President, Mr. Chairman, members and guests of the American Railway Engineering Association:

The decision to reorganize the material contained in Chapter 6 of the Manual is a natural one in light of today's expanding technology. A review of the contents of Chapter 6 shows that 260 of 323 pages, or 80 percent, of the Manual information is in the form of specifications for various materials and methods of construction used in the process of constructing a building. Only 63 pages, or 20 percent, of the Manual material is directly related to design standards for various types of railway buildings.

Specifications which set forth the quality of materials and their application in building construction are of importance to the railway architect and engineer. They are not, however, unique to the railway industry. The same specifications which are applicable to railway buildings are used in all types of building construction throughout the country. Typical specifications for building components, therefore, may be found in a variety of sources other than the AREA Manual. The wisdom of compiling such specifications for the Manual and maintaining them to reflect the best current practices is, therefore, open to question. It is not to be denied that such practice was, in the past, desirable as other sources of information were not readily available. Such is not the case today. Information of this nature can be found in a variety of sources such as manufacturer's literature, local building codes and industry and trade association standards. Individual railroads have, for the most part compiled a set of standard specifications from which they draw information for specific buildings.

In the past decade, many new products have been introduced into the field of building construction. To maintain a set of specifications which would contain all of the new products and advance methods of construction would require a much larger Chapter in the Manual and would still most likely be out of date before the printed changes could be distributed. It would also completely occupy the time of the members of this committee so that little else could be undertaken.

It has, therefore, been the decision of this committee to de-emphasize the specification material and place greater emphasis on the problems of designing and constructing buildings which are unique to the railway industry.

In order to accomplish this goal the present information in Parts 1 through 19 of Chapter 6 of the Manual would be deleted and replaced by an outline type specification. This outline, rather than attempting to present a complete specification for a building component, would attempt to guide the specification writer by giving him a check list of items to be considered, and by providing him with a suitable cross-reference and bibliography of information available from other sources. Thus, an outline type specification would be in far less danger of being outdated and would not require a maximum effort to keep it current.

This course of action will permit us to devote the larger portion of the Chapter to the problems of building design. Most of the structures with which we deal are unique to the railway industry. Stations, diesel and car shops, towers and many other structures, although similar in some respects to other industrial buildings, are found only in our industry. There is very little information available from other sources on the design and construction of these buildings. Today there are new building requirements developing within the industry. Facilities for piggyback and automobile handling, and facilities for crew housing are becoming a design problem. There are virtually no standards or recommendations available to guide the architect in these areas. Therefore, it will be the goal of this committee to attempt to provide some useful information while these problems are current.

Each major building type will be assigned a part in the Manual and a format will be developed so that each building type will be presented in the same basic manner. It is intended to write these parts so they will present the architect with the proper criteria in his execution of the design. The format will be so constructed as to cover the major topics for each type of building. The following topics would be discussed:

1. Site considerations for the building, including relationship to other buildings and functions, parking facilities and access.
2. Special requirements within the building and flow diagrams showing relationship between spaces.
3. Functional requirements.
4. Structural considerations to include recommended floor design loadings.

5. A guide to the proper selection of finish materials for floors walls, ceilings and component building parts.
6. Mechanical requirements and services to be considered.

It would not be intended to create a package design but, instead, a guide by which the architect may design his individual buildings. It is realized that in the majority of cases an optimum design is not feasible, and by no means would the building requirements as set forth in these portions of our Chapter be considered to be standard practice. Each building is subject to many limitations imposed by local conditions, codes and economic and individual railway requirements. Nevertheless, these parts of the Chapter, together with the limiting conditions, will enable the architect to consider all aspects of the total design.

In undertaking the reorganization of Chapter 6 of the Manual, this committee is attempting to provide the information that is needed at a time when it is needed.

A schedule has been set up by which this will be accomplished. A block outline of the reorganization has been presented to the subcommittee on revision of the Manual. This schedule calls for the revised guide-line specification portion to be completed by 1969. The parts containing design criteria for individual building types will be presented in conjunction with other subcommittees of this committee as they are developed in accordance with the new format.

Although a thorough reorganization of a Chapter in the Manual as I have outlined is a major undertaking, I am certain that the benefits to be derived from our work will be well worth our investment of time and effort.

Assignment 2—Buildings, Platforms, Ramps, Paving, Lighting and Other Facilities for Piggyback Terminals

Chairman Humphreys: C. R. Madeley, supervising engineer for the Southern Pacific, will now report on fixed property for piggyback terminals.

C. R. Madeley: Mr. President, members and guests:

As a part of its continued study of piggyback terminals your committee felt the Association should be apprised of the progress in piggyback and the activities of the National Railroad Piggyback Association.

As the AREA representative to the National Railroad Piggyback Association, I have had the opportunity to attend several of its meetings over the past two years. This Association was formed just 3 years ago with a membership of 28 railroads, and now has a 42-railroad membership. It has only 5 committees, and all business matters are handled by correspondence or open discussions at their quarterly meetings.

The NRPA is a non-regulatory body, but through resolutions passed by the Association, it makes recommendations for improvements to regulatory bodies such as the AAR, the Truck–Trailer Manufacturing Association and rail car manufacturers concerning equipment changes and standards. Its stature is growing rapidly and it has made almost unbelievable progress in this short period of time. This can be attributed to the outstanding leadership it has had, and a membership dedicated to providing our customers with better service.

At the June 1967 meeting of the NRPA, Joseph McKeefery, assistant traffic manager for Du Pont, in addressing this association stated that if the railroads solve the problem areas of service, terminal inefficiencies, rates, equipment and tariff restrictions, he doubted that the rail carriers could handle the tremendous volume these changes would bring. He also stated, and I quote, ". . . these are all solvable problems. Usually the men with the talent to solve them do not have the time; the men with the time do not have the talent. The key is for railroad management to find the man, give him the time and authority to use the talent."

Many railroads have recognized these problems and the potential of this service. They have created new departments to handle this service, headed by people with titles such as vice president, assistant to the president and many others. These same people form the membership of the NRPA which is working day and night to solve these problems, and when they do—look out!

Piggyback was, and still is, thought of as a trucking operation by many railroaders. Piggyback is a railroad operation, with terminals being the major source of lost profit, customer complaints and inefficiencies. Many of the inefficiencies were built in due to economic conditions and the rapid growth of TOFC, which did not allow time for engineering studies of terminals to be made. As business increased we simply added another track and created more inefficiencies.

At the March 1966 AREA Convention this committee presented a panel discussion on the various TOFC loading methods. In my opening remarks I stated that TOFC was a most controversial and changing subject, with facilities becoming outmoded almost before they are completed. This still holds true today, for now containers have caught the fancy of transportation people all over the world.

The economics of containeriztion and competition for foreign trade has prompted the large steamship lines to convert to containerships almost overnight. Japan is readying 25 new containerships for container movement to U. S. ports in the next two years. Ship-container terminals are being constructed at many of the world ports.

The enthusiasm of the steamship lines has spread to the American railroads, many of which have respresentatives in Europe and Japan to promote containerized foreign trade between the two continents, with the United States as a land bridge. Transcontinental COFC trains can cut about 10 days off shipping time via the Panama Canal.

The capture of national and international freight by the airlines is fast becoming a major threat. Several airlines now have container planes and can convert passenger planes to container planes in a matter of hours. They have modern and mechanized freight terminals for speedy delivery. By early 1970 the giant Boeing 747 supersonic jet freighter will be in service to capture even more of the freight market.

The national highway system continues to grow with superhighways aiding the trucking industry. Some states are now permitting truck-trailer trains of several trailers length over these superhighways and toll roads.

Senate Bill S.2658 is now being considered to revise the 1956 Interstate Highway System Law. This legislation has no specific gross-weight limit. It would determine this by a formula which could permit gross weights of around 125,000 lb, with increased axle load limits of 20,000 lb single and 36,000 lb tandem. It would increase the width limit by 6 inches, bringing it to 102-inches, but there would be no height or length limits.

The container explosion on the high seas and in the air, plus meeting the shippers need for a complete service, are leading railroads to develop a complete intermodal system. The railroads must be able to handle highway, steamship and airline containers plus whatever the shipper demands. If the traffic is right, you can be sure that a customer will get what he wants in any size or shape.

Standard sizes for containers have been agreed upon, but users are reluctant to abandon their own non-standard equipment, which has been tailored to their individual needs and represents large investments. Until all modes of freight carriers standardize on equipment, the exotic automated freight terminals you read about will still be a dream.

TOFC is here to stay and containers are coming on strong with a predicted growth rate equal to, if not more phenomenal than, TOFC has experienced. The new Santa Fe Super "C" piggyback train has proven some significant advantages in terms of motive power requirements and fuel consumption of the container trains. These will be vital factors for railroads offering a dependable high-speed, long-distance service to compete for premium freight now handled by trucks and air freight.

Major rail terminals will require improved TOFC/COFC facilities with modern and efficient unloading methods. There have been many complaints of excessive equipment down-time and maintenance cost of some equipment now in use. Some of the complaints directed at equipment manufacturers are justified, but most are not, because the older machines were not designed to handle the volume and weights that were forced on them by increased business. Equipment suppliers are developing new machines and constantly improving equipment and their reliability.

Selection of proper components to make up a TOFC/COFC unloading machine have a direct reflection on the dependability, reliability and maintenance cost of the machine in performing the "Duty Cycle" expected. The "Duty Cycle" is the moving of a rated load at required speeds over given distances within a stipulated period of time, operating continuously for a 24-hour day over the desired machine life. It is not sufficient merely to state that a 2-minute unloading and loading cycle is desired. The so-called magic "2-minute" loading cycle requirement stressed by the piggyback people may or may not be critical; it depends on the terminal loading and unloading pattern. In most cases the trailer delivery cycle time exceeds the loader time, thereby setting the pace for the transfer time.

As I have stated before, piggyback is a railroad service and its terminals are a major cost factor. It behooves each of you as railroad engineers to know all about this phase of railroad service and its various unloading methods and machinery, to assist—not resist—the TOFC departments of your railroad in planning and designing efficient facilities and selection of equipment to perform these services.

The Chicago area has about every type of loading machine available today, and as many different yard layouts. It would be time well spent to take a tour of these facilities while you are in the Chicago area.

Your committee will continue its study and submit recommendations in 1969.

Assignment 5—Computer Uses for Railway Building Design

Chairman Humphreys: Joe Penner, assistant architectural engineer for the Penn Central, will give our final report. Joe is chairman of Subcommittee 5.

J. A. Penner: Mr. President, members and guests:

The computer removes the human drudgery from engineering calculations and permits the engineer or architect to devote his full attention, initiative and energy to the engineering aspects of his job. This atmosphere promotes original thinking because the engineer can obtain answers to his questions and can evaluate new and different approaches to his problems without facing the dreary thought of long hours of calculations to find which solution is the best one.

Computers give the engineer the capability of easily simulating the environment that a facility will be subjected to throughout its design life. Thus, instead of designing a facility for one set of design criteria and hoping that the critical conditions have been selected, computers can be used to analyze a proposed facility for a wide range of possible conditions. This simulation will yield knowledge and insight of the way a potential design will react to its environment and allow the intelligent selection of design criteria.

The basic application of all computers is the solution of repetitive, time consuming mathematical equations.

To better acquaint you with what we on Committee 6 hope to develop in connection with computer usage and just what computers can do to help solve many engineering and accounting problems, I would like to list some practical applications of computer technology as applied to building construction and some of its related fields.

1. We can do many types of construction estimating with computers by inputing the various materials and labor costs and upgrading them as the prices vary with time and location.
2. Jobs can be scheduled using the Critical Path Method (CPM), Program Evaluation Research Task (PERT) or a number of other techniques which have been developed in the last few years.
3. In the field of specification writing, standard specification sections can be programmed and pulled out as they are needed on a particular job.
4. The variations of the many building codes throughout the country can be programmed so that we may eliminate the time-consuming process of comparing these many codes. This may help us in the future to standardize the construction of railroad facilities throughout the nation.
5. We can set up heating and cooling loads so we can computerize the procedure for calculating the maximum and minimum cooling and heating loads of a building in order to select the size of the equipment.
6. Piping flexibility analysis can be programmed so that we can compute the forces, moments, stresses and deflections in a piping system caused by thermal conditions and external loadings.
7. In the engineering field many programs have already been written for the structural design of buildings and bridges. Programs are being developed for the rating of many types of railway bridges. In almost all aspects of civil engineering, programs are being developed.

It is the intention of this subcommittee to work directly with Committee 32—Systems Engineering and to make recommendations to them to further investigate specific programs concerning the design and construction of railroad buildings and facilities.

Chairman Humphreys: Mr. President and members of the Association, this concludes our presentation. I would like to thank the subcommittee chairmen for their active participation during the past year, and also thank you gentlemen for your kind attention.

President Hutcheson: Thank you for those reports, Mr. Humphreys. The efforts of yourself and the members of your committee are greatly appreciated. You are all to be commended for undertaking the major work of revising your Manual chapter. Good luck.

Mr. Humphreys, your committee is excused with the thanks of the Association. (Applause)

Discussion on Masonry

(For report, see Bulletin 611, pages 403–447)

President Hutcheson: Committee 8—Masonry, will be our next reporting group. The chairman of this committee is R. J. Brueske, division engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Milwaukee, Wis.

Mr. Brueske, you may proceed when you are ready.

R. J. Brueske: Mr. President, fellow members and guests.

Your committee's report was published in Bulletin 611 of January 1968 and the Manual changes are printed in Bulletin 610 of December 1967.

Your committee is currently preparing new specifications for concrete poles and pole embedment. We are also reviewing the specifications for aggregates used in concrete and expect to bring them up to date.

We currently have tests underway at the AAR Research Center to determine the protection provided by the various substances used as a protective cover over butyl rubber membrane waterproofing. Our initial results have been very revealing. We are certain, when the final results are in, members of the Association will find the information gained of great value in deciding what protective cover to use on the butyl rubber membrane waterproofing.

We are also studying the desirability of including ultimate strength design in our masonry design specifications.

I ask that the following subcommittee chairmen stand and be recognized:

W. R. Wilson, assistant bridge engineer system, Santa Fe Railway, Subcommittee on Revision of Manual.

F. A. Kempe, Jr., district engineer, Northern Pacific, Subcommittee on Design of Masonry Structures. Mr. Kempe is also vice chairman of Committee 8.

G. W. Cooke, consulting engineer, chairman of the Subcommittee on Foundations and Earth Pressures, could not be here today.

J. M. Williams, bridge and building supervisor, Elgin, Joliet & Eastern Railway, chairman of the Subcommittee on Waterproofing for Railway Structures.

Assignment 6—Prestressed Concrete for Railway Structures

Chairman Brueske: Subcommittee Chairman J. R. Williams, engineer of bridges, Chicago, Rock Island & Pacific Railroad, will now discuss the work we have done under Assignment 6.

J. R. Williams: Mr. President, Mr. Brueske, fellow members and guests:

Your subcommittee is currently working on the design of a prestressed concrete tie for open-deck bridges.

Another assignment of this subcommittee is the preparation of designs of prestressed concrete box girders over a wide range of span lengths and various span depths. Design tables and accompanying text were published in Bulletin 611, January of this year, as information. With editorial revision, this material will be summitted for adoption in the Manual next year.

These tables contain the necessary design data for 3-ft and 4-ft-wide single-box beams, 6-ft, 7-ft and 7-ft 6-in-wide double box beams, all in several depth increments, with straight and harped strands and with and without tension in the top flange. Span lengths range up to 84 ft for some of the single boxes and up to 50 ft for some of the double-box designs.

The design tables and text were prepared by Clifford L. Freyermuth, structural engineer, Design Section, Engineering Services Department of the Portland Cement Association, using their IBM 1130 Computing System. The hundreds of man-hours spent by Mr. Freyermuth on this work, together with the computer time donated by the Portland Cement Association, are gratefully acknowledged.

Your committee also wishes to express its thanks to the Southern Pacific Company for making its computer program available to the Portland Cement Association for this work.

CHAIRMAN BRUESKE (continuing): That concludes the formal report of Committee 8.

At this time it is my pleasure to present our special feature, an address by A. K. Howe, chief engineer, Technical Service of Sika Chemical Corporation who will speak on admixtures for concrete.

Mr. Howe received his degree in civil engineering from the Yale School of Engineering. He is an associate member of AREA and Committee 8, and a member of ASCE, ACI, American Railway Bridge & Building Association, Roadmasters & Maintenance of Way Association and the Society of American Military Engineers.

Mr. Howe started his civil engineering career with the Pennsylvania Railroad and also worked for the Long Island Railroad before joining the Sika Chemical Corporation.

Mr. Howe has contributed much to the work of Committee 8 and former Committee 29, Waterproofing, whose work has been taken over by Committee 8.

Gentlemen, it is my privilege to introduce Art Howe.

Admixtures for Concrete

By ARTHUR K. HOWE

Chief Engineer, Technical Service, Sika Chemical Corporation

Mr. President, Mr. Chairman, fellow members and guests:

Admixtures are defined by the American Society for Testing and Materials, the American Concrete Institute and the Portland Cement Association as materials other than portland cement, water and aggregates that are added to concrete, mortar or grout immediately before or during mixing.

Admixtures are not really new. The great Roman builders were well acquainted with them and used them intelligently. Aqueducts and other great concrete masonry structures built by the Romans in Northern France, Germany and Great Britain were constructed of concrete containing oxblood as an admixture. Oxblood is an excellent air entraining agent.

During the 1920's it was common practice for farmers to add Gold Dust soap powder to their concrete as a waterproofing agent. The Gold Dust material was high in stearates and probably did as good a job as any expensive water repellent on the market.

In the early 1940s the benefits of air entraining agents in highway concrete were observed and their use increased rapidly. By 1948, 10 percent of all the concrete placed in the United States contained some type of admixture. In 1962, reports showed that admixtures were being used in 50 percent of all concrete placed. Their specification and use has been increasing steadily from year to year. In 1966 the Admixture Committee of the Highway Research Board of the National Academy of Sciences reported that water-reducing and set-retarding admixtures were being used in 50 to 60 million cubic yards of concrete per year in the United States and Canada.

At the present time in Chapter 8 of the American Railway Engineering Association Manual of Recommended Practice under Part 1—Paragraph B, "Cement" the use of air entraining cements and air entraining agents is permitted. In addition, in the Prestressed Concrete Structures Section, Part 17—Paragraph Q, "Concrete", it is stated that certain other admixtures (with the exception of calcium chloride) may be used if they are proven by test to be beneficial to fresh or hardened concrete.

Several railroads in the United States specify not only air entraining agents but also fly ash, retarders, accelerators and water reducers conforming to ASTM standard specifications.

The report of the American Concrete Institute Committee 212—Admixtures, published in the November 1963 issue of the *Journal of the American Concrete Institute*, lists 15 types of admixtures for concrete, mortar and grout, as follows:

1. Accelerating admixtures
2. Water-reducing admixtures and set-controlling admixtures
3. Grouting admixtures
4. Air-entraining admixtures
5. Air-detraining admixtures
6. Gas-forming admixtures
7. Expansion-producing admixtures
8. Finely divided mineral admixtures
9. Dampproofing and permeability-reducing admixtures
10. Bonding admixtures
11. Chemical admixtures to reduce alkali-aggregate expansion
12. Corrosion-inhibiting admixtures
13. Fungicidal, germicidal and insecticidal admixtures.
14. Flocculating admixtures
15. Coloring admixtures

Of these 15 the following are considered the most widely used commercially available admixtures for structural or mass concrete:

1. Accelerating admixtures
2. Water-reducing and set-controlling admixtures
3. Grouting admixtures
4. Air-entraining admixtures
5. Finely divided mineral admixtures
6. Dampproofing and permeability-reducing admixtures

The American Society for Testing and Materials further refines the classification of chemical admixtures, and in ASTM Specification C 494-65T we find the following:

Type A—Water-reducing admixtures
Type B—Retarding admixtures
Type C—Accelerating admixtures
Type D—Water-reducing and retarding admixtures
Type E—Water-reducing and accelerating admixtures

Air entraining admixtures are described sparately in ASTM C 260-65T.

The basic constituents of these commercial chemical additives are salts of lignosulfonic acid, salts of hydroxylated carboxylic acid, triethanolamine and its salts, neutralized Vinsol resin and calcium chloride. Singly or in combiation, the chemicals result in admixtures for concrete.

These admixtures affect virtually all of the properties of concrete. The properties most affected and of greatest importance are water reduction, workability, setting time, strength (both compressive and flexural), shrinkage and durability. Since water reducers, water-reducing retarders, accelerators and air-entraining agents comprise the bulk of admixtures used, this discussion will concentrate on their effects on the above properties of concrete.

Air-Entraining Admixtures

Air entraining agents have two uses: 1) to render concrete frost resistant and 2) to impart workability to lean concrete and concrete made with aggregate deficient in fines or harsh lightweight aggregates.

The sole benefit of any air-entraining agent is its ability to entrain air into the mix. In plastic concrete the only function of an air-entraining agent is to supply a flexible aggregate (very fine air bubbles). The air bubbles give air-entrained concrete its cohesive, rubbery workability.

Accelerating Admixtures

Although there are quite a few chemicals available which accelerate the hydration of portland cement, the one most universally used is calcium chloride. Practically every accelerating admixture sold contains calcium chloride.

Accelerating admixtures are used: 1) to increase rate of early strength development, 2) to decrease the time of setting, or both.

Some of the benefits of early strength are: 1) earlier removal of forms, 2) reduction in time needed for curing and protection, 3) shorter construction time and 4) faster repair of a structure.

The benefits of reduced setting time are: 1) earlier finishing of surfaces, 2) reduction of pressure on forms and 3) faster sealing of leaks against pressure.

The use of calcium chloride in admixtures can be both advantageous and detrimental to concrete depending principally upon the amount used.

The resistance of concrete to freeze-and-thaw cycles is increased at early ages as is resistance to abrasion.

Calcium chloride increases both compressive and flexural strengths at early ages. The ultimate strength at one year or more, however, will vary depending upon mixing and placing temperatures. As an example, concrete mixed and placed at 40 F will have higher ultimate strength than plain concrete. However, concrete mixed and placed at 70 F will have lower ultimate strength than plain concrete cast at 70 F or above.

The use of calcium chloride will increase the drying shrinkage of concrete. Volume changes during alternate cycles of wetting and drying will be increased.

The rate of temperature rise due to heat of hydration is increased and the maximum temperature is reached earlier. Therefore, stresses caused by greater thermal expansion and contraction will also be greater.

It should be remembered that calcium chloride is not an anti-freeze although it is commonly considered as such. Calcium chloride in the proportion of 2 lb per sack of cement will lower the freezing point of concrete mixing water only 3 deg—from 32 F to 29 F.

Water-Reducing and Retarding Admixtures

Water-reducing admixtures and retarding admixtures, also known as set-controlling admixtures, are grouped together by the American Concrete Institute report. ASTM Specification C 494 considers them separately and in combination.

All water reducers are basically retarders which have been modified by additional chemicals so that they do not affect setting time.

Drying shrinkage of concrete is affected by the use of water reducers and retarders. The salts of hydroxylated carboxylic acid will reduce the drying shrinkage to the greatest degree.

All water reducers and retarders increase strength beyond that obtained by water reduction alone. Strength does not necessarily follow increase in dosage. The salts of hydroxylated carboxylic acid will increase strength as the dosage is increased. Within narrow limits the salts of lignosulfonic acid will increase strength in proportion to quantity used. Since strength is increased, it is sometimes possible to reduce cement content of the concrete by use of these admixtures.

It is possible to reduce the slump loss in concrete by the use of retarders and even possible to regain lost slump by the use of retarders.

In hot weather the setting of concrete is accelerated, water requirements are increased and slump is reduced. Since some of these retarders are single purpose retarders and retard and reduce water in proportion to the quantity used, they can be used to offset the effects of high temperature on concrete. By increasing the proportion used with temperature, uniform slump, water-cement ratio and setting time can be obtained regardless of the ambient temperature.

To use admixtures properly, we must be able to control their action by adding them at the concrete mixer in varying proportions, either alone or in combination, to suit the job at hand. They should be tested and evaluated by reliable laboratories in trial mixes under job conditions using the specified cement, aggregates and local water.

In winter we may need an accelerator or, if it is exposed slab work, an accelerator plus an air-entraining agent or, for structural purposes, an accelerator plus a retarder.

Structural shapes exposed to frost may require a retarder plus an air-entraining agent. In hot weather we may want to increase the quantity of retarder to offset the undesirable acceleration and high water requirements of high temperature. Pozzolans such as fly ash should be added with all the admixtures where alkali reactive aggregate must be used.

Concrete can thus be controlled by the use of admixtures to suit the structure, type or gradation of aggregates and job conditions.

Although it has been proven by laboratory test and in actual construction that admixtures have profound effects on the properties of concrete in both the plastic and hardened states, admixtures never should be used as substitutes for good concreting practices, such as proper mix design, careful placing and adequate moist-curing. An admixture should be considered an additional ingredient or tool to aid in obtaining uniform, strong concrete.

In closing, I would like to show some slides of various types of projects in which admixtures were used to good advantage.

(Mr. Howe then showed and commented on some 30 colored slides, none of which is reproduced herein.)

(Applause)

CHAIRMAN BRUESKE: Thank you, Mr. Howe, for an interesting and informative address. With the increasing use of concrete on the railroads, we welcome the opportunity to be brought up to date on the most recent advances in admixture for concrete.

Mr. President, this concludes Committee 8's presentation.

PRESDENT HUTCHESON: Mr. Brueske, we thank you and the members of your committee for your efforts during the past year. The design table for precast–prestressed box girders certainly are a valuable addition to the data available to our bridge engineers. Please convey our sincere appreciation to Clifford L. Freyermuth, structural engineer for the Portland Cement Association, and the PCA for their valuable contribution to our Association.

Mr. Howe, please accept our grateful thanks for your interesting and informative discussion of admixtures for concrete. Your continued contributions to the work of our important Committee 8 are greatly appreciated.

Mr. Brueske, your committee is excused with the thanks of the association.

Discussion on Maintenance of Way Work Equipment

(For report, see Bulletin 610, pages 329–335)

PRESIDENT HUTCHESON: The next-to-last committee to report at this afternoon session is Committee 27—Maintenance of Way Work Equipment, the chairman of which is R. M. Johnson, production engineer, Western Maryland Railway, Hagerstown, Md.

Mr. Johnson, the microphone is yours when you are ready to proceed.

CHAIRMAN R. M. JOHNSON: Mr. President: The reports of Committee 27, will be found in Bulletin 610, Vol. 69, pages 329 to 335. We are reporting on seven assignments, and our presentation will be confined to a brief summary of the published reports, and a short progress report on the remainder.

Assignment 1—Revision of Manual

CHAIRMAN JOHNSON: The committee reviewed the material in Chapter 27 of the Manual, and it was the consensus that no changes are necessary at this time.

Assignment 1 (a)—Revision of Handbook of Instructions for Care and Operation of Maintenance of Way Equipment

CHAIRMAN JOHNSON: C. R. Turner, superintendent work equipment, Denver & Rio Grande Western, Denver, Colo., is chairman of Subcommittee 1 (a). The committee has reviewed all material in the Handbook and is now compiling the reports. Mr. Turner, will you please rise for recognition? Mr. Turner is also vice chairman of Committee 27.

Assignment 2—Improvements to be Made to Existing Work Equipment

Chairman Johnson: Emil Eskengren, process engineer, St. Louis–San Francisco Railway, Springfield, Mo., is chairman of Subcommittee 2. This committee has been jointly involved in correcting the Handbook in conjunction with manufacturers. No specific report is presented on this subject at this time. Will Mr. Eskengren please rise for recognition.

Assignment 3—Switch Heaters and Other Devices or Machines for Removing Snow from Switches

Chairman Johnson: J. W. Risk, superintendent work equipment, Canadian National Railways, Toronto, Ont., is chairman of Subcommittee 3 and will now give a summary of his report, which is a progress report, presented as information.

J. W. Risk: The report on switch heaters and other devices or machines for removing snow and ice from switches is a follow-up to that published in the Proceedings, Vol. 68, 1967, pages 255–262.

It is the considered opinion of the committee that the most important factor in switch heater development is tests undertaken by the National Research Council of Canada in collaboration with the Canadian Pacific and Canadian National Railways in 1966–67 and 1967–68.

Field and laboratory tests with propane-gas and fuel-oil-burning heaters have established that unless some form of enclosure is provided at the switch, the loss of heat to the atmosphere is such that all heaters failed to perform efficiently under less than extreme conditions.

To insure the proper operation of the switch, heat from any type of heater must be directed up through the openings between the switch point and the rail. This method has been used in testing heater performance down to —25 F with snow fall of 1 inch per hour and winds up to 45 mph with entirely satisfactory results, whereas previous tests with the same heaters resulted in failure at +15 F under the same conditions of snow and wind.

The National Research Council and the railways mentioned will continue the tests of the heaters and heater control devices, and their findings will be submitted in subsequent reports of this committee.

Assignment 4—Selection and Installation of Road-Rail Attachments

Chairman Johnson: L. W. Cantwell, assistant engineer, Atchison, Topeka & Santa Fe Railway, Chicago, is chairman of Subcommittee 4.

The committee has assembled extensive information for a report to be submitted in the near future. Will Mr. Cantwell please rise for recognition.

Assignment 6—Track Lining Equipment

Chairman Johnson: T. H. Taylor, supervisor maintenance of way material and equipment, Penn Central, Chicago, is chairman of Subcommittee 6, but he is not here today.

Assignment 7—Rail Laying Equipment

Chairman Johnson: R. O. Cassini, engineer work equipment, C&O–B&O Railroads, Huntington, W. Va., is chairman of Subcommittee 7, but he is not here either.

A survey of equipment used by various railroads and other additional information is needed to prepare a report, which will be done in the future.

Chairman Johnson (continuing): If there are any questions pertaining to our reports, the committee will attempt to answer them. If there are no questions, Mr. President, this concludes the report on our assignments.

President Hutcheson: Thank you, Mr. Johnson, for that report on your committee's work during the past year. Committee 27 plays a particularly important role in the Association's contribution to the railroad industry.

Your committee is excused with the thanks of the Association.

Discussion on Economics of Railway Labor

(For report, see Bulletin 609, pages 193–213)

President Hutcheson: Gentlemen, the final report to be presented this afternoon is that of Committee 22—Economics Of Railway Labor. This is one of the most important committees of the Association and has a close place in my own heart because the first committee work which I did with the Association was on Committee 22.

The chairman of this important committee is one of our directors, Harold W. Kellogg, regional assistant chief engineer, Chesapeake & Ohio Railway—Baltimore & Ohio Railroad, Richmond, Va.

Don't hesitate to ask Mr. Kellogg and his committee any questions you might have.

Chairman H. W. Kellogg: Committee 22 has prepared for publication in the Proceedings, memoirs in honor of three of its former members—E. J. Brown, H. E. Kirby and J. G. Begley. The memoirs follow:

Elzear Joseph Brown
1900-1968

Elzear Joseph Brown, retired assistant vice president operations, and former chief engineer, Burlington Lines, Life Member, past president and former director of American Railway Engineering Association, died at La Grange, Ill., on January 3, 1968, at the age of 67.

Mr. Brown was born on December 1, 1900, at St. Joseph, Mo. He attended Christian Brothers College at St. Joseph and St. Patricks Academy in Chicago.

Mr. Brown was an active member of the AREA, which he joined in 1939. He had served on Committee 22—Economics of Railway Labor, 1940–1968; Committee 5—Track 1945–1959; Committee 31—Continuous Welded Rail 1952–1968; was director, 1955–1958, junior vice president, 1958–1959; Senior vice president, 1959–1960; president, 1960–1961. He became a Life Member upon his retirement from active railway service.

In March 1955 he became a member of the AAR Detector Car Committee and served as its chairman from December 1958 to June 1967. He also served on the AAR General Committee on Waterway Projects from 1962 to 1967.

He was a member of the Maintenance of Way Club of Chicago (president 1936–1937), Maintenance of Way Club of St. Louis, American Railroad Bridge and Building Association and Roadmasters & Maintenance of Way Association of America (president 1946–1947).

Mr. Brown joined the Burlington in 1918 and held various positions until February 1, 1943, when he was made engineer of track. On January 1, 1953, he became assistant chief engineer. He was promoted to chief engineer on January 1, 1955, and assistant vice president operations May 1, 1966. He retired June 1, 1967. Among the important projects carried out under his direction as chief engineer of the Burlington were: The Quincy Bridge over the Mississippi River, 1,850 ft long, at a cost of $4,250,000; three major centralized traffic control projects; four main-line relocations; new freight houses constructed in Chicago, Berwyn, Ill., Kansas City, Mo., and Lincoln, Neb.; a hump retarder yard at Cicero, Ill., and a new diesel shop at Lincoln. In addition, he inaugurated the Burlington's welded rail program.

In the passing of Mr. Brown the railroad engineering profession, particularly the American Railway Engineering Association, lost a pillar of strength, and his host of friends have lost the comradeship of a real man.

Mr. Brown was a member of St. Francis Xavier Roman Catholic Church in La Grange. Survivors include his wife, Alice; two sons, John and James; a brother, the Reverend John F. Brown, and a sister, Mrs. Mary Rose Casey. The Reverend Donald Brown, a brother, preceded him in death.

H. E. Wilson
M. S. Reid
T. L. Kanan
Committee on Memoir.

Herman E. Kirby
1903-1968

Herman E. Kirby, 64, a Life Member of the AREA and retired cost engineer—system of the Chesapeake & Ohio, died on January 28, 1968, after suffering a heart attack in his home at Huntington, W. Va. He had retired in 1962 because of ill health. Mr. Kirby had served with dedication as a member of the AREA since 1929. In 1949 he was appointed chairman of Committee 22—Economics of Railway Labor and later became a Member Emeritus of that committee. He had also served as vice chairman of Committee 24—Cooperative Relations with Universities, and was also elected a Member Emeritus of Committee 24.

Mr. Kirby had been active in other groups in and out of the railroad field. He served as president of the Roadmasters' and Maintenance of Way Association in 1946 and was later elected an honorary member of that association. On the occasion of the 75th anniversary of the Roadmaster's Association he was chosen to make an address on the history of the organization. He was a fellow of the American Society of Civil Engineers and a member of the Engineers Club of Huntington.

Among other activities Mr. Kirby served as chairman of the Tri-State Technical Societies in 1959, and as a member of the boards of directors of the West Virginia Heart Association and the Cabell–Wayne–Lincoln Heart Association. He was a member of the Kiwanis Club of Huntington, the Mensa Society and the Guyan Golf and Country Club.

A native of Alderson, W. Va., Mr. Kirby was born on September 2, 1903. He studied civil engineering at West Virginia University and in later years he took extension courses in motion study and job analysis at the University of Virginia, in business statistics at the University of Richmond, (Va.) and in industrial management at Virginia Polytechnic Institute.

During summer vacations while attending college and later, Mr. Kirby held positions with the State Road Commission of West Virginia and the State Road Department of Florida. He entered the service of the C&O on September 1, 1926, as a rodman and acting instrumentman. On January 31, 1927, he became a draftsman in the office of the engineer maintenance of way. On July 14 of the same year he was named assistant cost engineer on the Clifton Forge division, being transferred to the office of the system cost engineer on May 1, 1929. On August 1, 1936, he was promoted to assistant engineer, and on July 1, 1947, he was further advanced to cost engineer—system with headquarters at Richmond, Va. In 1956 he was moved to the road's new headquarters at Huntington. Poor health forced his retirement on February 1, 1962.

Mr. Kirby is survived by his wife, Mrs. Louise Thorp Kirby, and a sister, Mrs. Oscar Boyd, Roanoke, Va. Mrs. Kirby is a member of the English faculty of Marshall University and president of the Huntington branch of the American Society of University Women.

A loyal friend—and he had many—Herman Kirby was a devoted family man. In conducting his personal and professional life he was a man of the highest character, striving always to give the best of which he was capable. His passing came as a loss to all who knew him and to the many organizations, including the AREA, to which he contributed so unstintingly of his time and talents.

M. H. Dick
R. G. Simmons
A. L. Maynard
Committee on Memoir.

John Graham Begley
1900-1967

John Graham Begley, retired assistant division engineer, Baltimore & Ohio Railroad, passed away on June 6, 1967 at Washington, Ind. He is survived by his widow, Jessie Fuller Begley; a daughter, Jane Begley Chattin and three grandsons of Toledo, Ohio; and a son, Captain George Alan Begley of the United States Air Force.

Mr. Begley was born August 14, 1900, at Dwale, Ky., and entered railroad service August 26, 1917, as a chainman on the S.V.&E. Division of the B&O. He advanced through the positions of cost engineer, assistant on the corps, track supervisor, assistant division engineer and division engineer; retiring July 4, 1964.

Mr. Begley joined the American Railway Engineering Association in 1928 and became a Life Member in 1966. He became a member of Committee 22 in 1963, and was active until the time of his death.

His associates in the railroad industry and fellow members of Committee 22 will miss him.

J. E. Sunderland, Jr.
J. W. Brent
A. L. Maynard
Committee on Memoir.

Chairman Kellogg: Mr. President, members of the Association and guests: The report of Committee 22—Economics of Railway Labor, appears in Bulletin 609, pages 193 to 213, incl. Following the reports on the assignments the committee will have a special feature, which will be illustrated, entitled "The Design and Construction of A. E. Perlman Yard," by C. T. Popma, assistant vice president—engineering, Penn Central, New York.

Assignment 1—Revision of the Manual

Chairman Kellogg: We have no report this year on Assignment 1. The chairman of this subcommittee is W. B. Throckmorton, chief engineer of the Chicago, Rock Island & Pacific Railroad, Chicago. I will ask Mr. Throckmorton to rise and be recognized.

Assignment 2—Analysis of Operations of Railroads that Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work

Chairman Kellogg: M. H. Dick, editor, Railway Track and Structures, is chairman of Subcommittee 2. Mr. Dick

Assignment 3—Labor Economies in the Use of Radio by Maintenance of Way Forces

Chairman Kellogg: W. J. Drunsic, division engineer—track, Penn Central, Utica, N. Y., is chairman of Subcommittee 3. Mr. Drunsic

Assignment 4—What Various Railroads Have Done to Effect Economies in Track Inspection

Chairman Kellogg: John Fox, assistant engineer of track, Canadian Pacific Railway, Montreal, Can., is chairman of Subcommittee 4. Mr. Fox

Assignment 5—Economics of Track Labor in the Maintenance of Continuous Welded Rail

Chairman Kellogg: N. H. Williams, bridge and building master, Delaware & Hudson Railroad, Albany, N. Y. is chairman of Subcommittee 5. Mr. Williams

Assignment 6—Economics of Maximum Mechanization in Yards and Terminals

Chairman Kellogg: J. W. Brent, assistant chief engineer—maintenance, Chesapeake & Ohio Railway–Baltimore & Ohio Railroad, Huntington, W. Va., is chairman of Subcommittee 6. Mr. Brent

Assignment 7—Labor Economies of Various Methods of Renewing Ties in Main Lines with Mechanized Forces, Related to the Density and Cycle of Renewals

Chairman Kellogg: R. G. Maughan, assistant chief engineer—maintenance, Canadian National Railways, Montreal, Can., is chairman of Subcommittee 7. The assignment will be continued. I will ask Mr. Maughan to stand and be recognized.

Chairman Kellogg (continuing): The next portion of our report will be a special feature on the design and construction of the A. E. Perlman Yard. It will be presented by C. T. Popma, assistant vice president—engineering, Penn Central Company, whom most of you know. Mr. Popma is also a member of Committee 22. Mr. Popma. (Applause)

The Design and Construction of A. E. Perlman Yard

By C. T. POPMA

Assistant Vice President—Engineering, Penn Central Company

C. T. Popma: All of us have worked for a number of years trying to program economical track maintenance. I think the last five years have shown remarkable development in the surfacing of tracks. We have now arrived at the point where we have fully automatic tampers. The last couple of years have been productive in the design of tie renewal machinery. As all of us see these strides toward better main-track maintenance, we shudder at the cost of maintaining our yards and terminals and we say to each other: somebody ought to do something about it. We ought to mechanize these forces.

Well I wonder if that is really what we want to do? Perhaps a better way is to take a look at our railway plant as built in the United States and ask ourselves, is this a modern plant? Is this a plant capable of handling trains that are 250 cars long? Is this a plant capable of servicing 6-unit diesels in 15 minutes so we can say we have efficient locomotive maintenance and facilities? Do we have efficient car repair facilities? Do we really have a yard that a yardmaster would love to run?

Unfortunately, if I asked myself these questions about the various facilities on Penn Central, in all sincerity I must say that our yards are obsolete. I think the engineers in 1909 did one heck of a good job in designing the 1909 terminals. But this is 1968 and we need a little different kind of facility than we had then.

With that thought in mind, Penn Central started in 1958 to redesign its railroad plant. One of the first yards constructed was Frontier Yard at Buffalo, N. Y. This is a truly modern yard. The next one was Conway Yard in Pittsburgh, another electronic yard. The next one was at Elkhart, Ind., the Robert R. Young yard. Next came the Gateway Yard at Youngstown, Ohio, followed by the Big Four Yard at Indianapolis, Ind.

From each and every one of these yards our engineers learned a lot of things. We learned different construction techniques, different ways of handling the paper work, different ways of handling the control of the cars. We learned to adapt ourselves from the old relay technology to a solid-state technology.

We brought ourselves up into the sixties with the idea in mind that Penn Central needed a Gateway Yard in the east. Our engineers toured many yards. We looked at yards on the Canadian National, Canadian Pacific, Southern Pacific, Norfolk & Western, and the Southern, trying to get all of the best ideas of today's technology.

With these ideas in mind we set out to design what we call the A. E. Perlman Yard at Selkirk, which is just outside Albany, N. Y. This yard is in the northeast section of our geographical territory, which extends all the way from St. Louis to Boston, all the way from Norfolk, Va., up to Montreal. This yard has a very critical place in our operations in that it funnels all New England traffic to the south and to the west, and distributes it throughout the rest of our system.

We assigned to our industrial engineers the task to figure out how many cars they felt, eventually, with the growth of the country and railroads' increasing participation in the movement of freight, would be handled through this Gateway.

We determined that maybe five to six years from now we could have a traffic flow approximating 6,000 cars. That being the case, we laid the groundwork. This yard must be capable of expansion to handle 6,000 cars a day with a double hump, 90 classification tracks, 12 receiving tracks and 12 departing tracks. This entire yard complex is to be controlled by one man from a yard control tower, a single yardmaster. He must have dials, readouts and printouts—the ability to command the computer to tell him exactly what is going on in that yard at all times. He must have instantaneous communication with every locomotive in the yard.

With this as a base we set out to design the yard.

A look at the track diagram would show that at the present time we are constructing nine departure tracks, two through running tracks, and a small local yard of 10 tracks. Nine receiving tracks are constructed in line with the hump. We are constructing 70 classification tracks. The receiving and departure tracks will be capable of receiving trains of 250 cars.

This yard will be truly an automatic yard. Following the recent concepts used for the A&S Yard at St. Louis, the Southern Pacific Yard at Eugene, Ore., and Brosnan Yard on the Southern, it uses a pair of G. E. digital computers for the control system and to continually track the movement of all cars in the complete yard.

The hump operation will be more or less conventional for an electronic yard; once a car is uncoupled, the car is weighed, radar determines the speed, the wind direction is checked and all this information is fed into a computer. The master retarder is actuated and we again recheck the speed. When the car goes through the group retarder we feed in the destination to which it is to be routed and then command the retarder to squeeze the wheels of the car so as to allow the car to roll to where it is to be coupled, at no more than 4 mph.

Most of this is rather conventional electronic circuitry using the latest devices on the market.

With the starting of the yard is became quite obvious that if we were going to spend $31,000,000 to build the yard, we must know the date the yard will go in service. In order to build the yard close to a point where formerly we had two yards, we had to almost eliminate those two yards and handle the switching that was formerly done there either at Springfield, Mass., Syracuse, N. Y., or Weehawken, N. J. We had to maintain train traffic through the yard at all times. But we down-graded the yard to be about a 6-track flat switching yard, giving the transportation group various pieces of the yard to do this type of work at all times. In order to be able to control the actual construction schedule and insure that we would be able to open this yard on July 1, 1968, we went to the Canadian National because that road had done more work in Critical Path Methods in the control of the railroad construction activities than anyone else we knew of. They were very cooperative. We used their program. We used G. R. S.'s computer to run the computation through every two weeks to up-date our critical path program to insure we would stay on schedule. One thing I can say about the use of this critical path program in a construction job: you don't wake up one morning and find you are in trouble. You know you are going to be in trouble about a month before you actually are into it, and this really helps. It doesn't necessarily cheapen the cost of the yard and it doesn't necessarily keep you out of trouble. The only thing it does is: it lets you know you are going to get into trouble before you actually get there.

In order to be able to control all construction activities immediately, we set up a radio base station and equipped all supervisory personnel with radio. Also, we insisted that our contractors use radio in the control of their operations, so at all times we could coordinate the complete construction job.

This construction was carried out over a length of about 7½ miles, which is the length of the yard, and a width of about a half mile. It involved about 2 million yards of grading, 123 miles of track and 325 turnouts. The grading equipment was more or less conventional, possibly with the exception of two machines. LeTourneau L-90s were brought in from southern Texas. This is a triple unit controlled by one man. Each machine has its own power and is capable of moving 90 yd of dirt at one time at 30 mph. With the long haul we had in the yard, this became a very economical machine. It required no pusher service for loading.

Another machine adapted by the grading contractor for use in track construction to accurately lay the subgrade was a highway type fine grading machine. This machine follows a guide line that is staked out by the engineer, both as to alignment and as to surface. There are two sets of feelers, one in front and one in the rear. These feelers sense their way along a taut cord and automatically raise and change alignment on the fine grading machine to insure that the subgrade is held to line and surface within about an inch. This is all done automatically, at a rate of a little better than a mile a day.

It was quite evident, from our past experience, that the flow of material was going to be tough. We had a ground rule when we started this yard that we would reuse every ounce of material in the old yard that we could and that we would buy no new material unless it was more economical to do so than to use secondhand material.

Fifty percent of the cross ties used were secondhand. Every other tie was a secondhand tie. We also used some panel track we picked up from other locations in order to insure that this material flow could be kept under control. Past experience indicated we needed a buffer zone. We needed some place to be able to store material while waiting for other materials to be released from a welding plant or while waiting for the grading contractor to get out of our way. So we sent our industrial engineers to the job site and told them to lay out the most efficient material yard you can build today. We told them to build into the yard two panel-type construction jigs and two panel turnout jigs. We also told them to set up a complete method of cleaning, disassembling, hard facing and rebuilding of the retarders. This material yard was the first item of work accomplished.

In the material-yard layout a coach for the staff forces engaged in the field construction was set up. It housed timekeepers to disburse all of the material that is put into the job, and served as the office of the transportation assistant whose responsibility it is to see that cars destined for the yard arrive on time.

A turnout panel jig was constructed by our forces on the site and in essence is built out of channel iron and rail. On this jig we can construct up to a No. 20 turnout. Switch ties were piled according to size. The next track is used for the operation of a tie handler to pick up the switch ties and place them individually into the jigs.

Since we decided that the entire classification yard would have all welded rail, the only joints we would permit were joints necessary to connect the switch points and the frogs. No others were permitted. The turnouts are to be all welded.

Turnout accessories such as switch plates, braces, etc., were shipped in 50-gal drums and stored according to size. So all we had to do was pick up a 50-gal drum and we had a complete set of accessories for a turnout. They were supplied that way either from the manufacturer or from one of our storehouses.

A multiple drill and saw were at the site to cut the welded rail into the proper lengths for assembling of the turnouts.

A Burro crane placed the rails on top of the plates after the ties had been set on the jig.

An eight-man gang constructed two turnouts per day. Each turnout is numbered according to location where it will be placed.

The turnout jig is serviced by a pipeline containing air outlets for boring tools, spike drivers, impact wrenches—so all the small tools are air powered.

Again borrowing from the technology of other railroads, we talked to the Elgin, Joliet & Eastern people and asked them if they would rent their turnout carrier to us for the construction of the yard. This machine was constructed by the EJ&E to pick up turnouts intact and move them to other points. The turnout carrier, promptly renamed the "Monster" by our personnel, moves the turnout from the jig to the actual site, which has been graded and surfaced. This machine is powered by a DW-20 Caterpillar tractor and is capable of traveling at 20 mph.

Econo Heat switch heaters (electric strip heaters) were applied to all switches. This type of heater was developed in Penn Central's research laboratories. Prior to its installation, the rail must be sand blasted and an epoxy applied to the stock rail; then the Econo heater is placed up against the epoxy and actually rolled into place.

One other method of track construction that was used in the yard was the use of prefabricated track panels. One of the main reasons we built the track in panels was: we found that it would be a little more economical to do so and later place the panels in the field than it would be by going out with each individual piece, such as the tie plates, rail and so forth, and assembling in the field. Also this method permitted the panel track construction gang to work the year around and actually store track panels for the time when the grading contractor was in our way. When he got out of the way we would then be able to lay tracks fast and catch up with him.

To fabricate the track panels a jig was built on the outside of a conventional track. It has small lugs welded on top of the rail to be sure the ties are spaced correctly and has a spacer block at the left of the side to line up one end at a time. After the plates were sorted the Burro crane places the rail on the jig, and the spike drivers spike it up. We also use multiple spike machines on this jig as we have them available. After the track panels were constructed they were placed in unfit cars and stacked ten high for future placement throughout the yard.

The next operation was placing the initial lift of stone after the sub-ballast was placed by the contractor; our forces used a Jersey spreader attached to a bulldozer and a fleet of trucks and hauling from a local quarry. We determined it was cheaper to apply the first lift by trucking it in rather than using a work train. The Jersey spreader laid down a perfectly even spread of ballast which was then compacted. The compactor used was a conventional road compactor. It made an excellent surface for track construction.

The track panel laying gang brought the panels on either X-cars, or on one of two flat beds that the Penn Central had at the site, and placed them with a truck crane. After this we used Penn Central's special ballast cars, which are Enterprise door cars, to distribute the stone.

Another different type of construction used in the classification yard where we desired all welded rails, and which we could not do with our prefabrication jigs, was to haul the ties out with flat-bed trucks, 16 to a bundle, place them in aisles and then cross lace them to make sure every other tie was a new tie. Tie plates were redistributed from the tailgate at the rear of a dump truck. Then a series of rollers were placed approximately every two rail lengths to permit welded rail unloading. A spacer pulled by a bulldozer pulls two rails at a time. It lays the rails down on the rollers. Then we came back with a conventional threader and placed the rail on the tie plates and spiked every sixth tie.

A Penn Central development, an automatic gaging machine, pushed by the spike driver brings the rail to gage. The operator has immediately below his feet a moving gage which at all times indicates whether the machine is working properly or not. We used hydraulic spike drivers with an automatic feed arrangement; two of them can do a mile of track a day.

The next machine used was a tie spacer and following that are rail anchor machines.

The next operation is stone unloading, using the Enterprise door cars. We used two different types of surfacing machines. One was an Electromatic Junior, with a Nordberg raising device attached to raise the track, followed by a multiple tamper. The other was an Electromatic Automatic tamper doing the job all by itself.

To raise the switches we had to develop a switch raising machine which was built at our Jackson shops. It actually will pick up a complete turnout, and by moving back about every fifth tie we complete the tamping with a R.M.C. switch tamper, or a Jackson switch tamper.

An assembly jig for retarders was also set up. The retarders were taken out of the old yard, cleaned in a separate heat bath, hard faced, brought back to new specifications and assembled in this jig. They were then mounted on one of our flat-bed trucks, trucked to the retarder location, and there put in place.

Our communications and signal forces worked together, as did our electrical contractors, in placing cable. We used a Kelley Cable Layer rig to actually plow our cable. We found this was the cheapest way of getting it in. Where we found we had very dense amounts of cable, we used a Dickinson machine.

One interesting point in the construction of this yard arose from the fact that the entire yard is built on Albany varved clay. Years ago a state building and an office building built on this type of ground collapsed after about five years. So we called in two soil consultants and received their opinions as to how much settlement we could expect at the hump. One of the consultants told us he would expect a settlement of about 5 ft in a year. The other one said it should not settle more than 6 in. So we had an interesting decision to make. Actually, we pieced together what we considered were the best recommendations of the two soil consultants; for the hump which would have a height of 26 ft we decided we would go down

5 ft and place sand piles and then place 5 ft of subballast overlaid with 2 ft of stone. Then we would preload it to a height 10 ft higher than the planned hump and continually monitor readings to see what would happen. After we had left the preload on for, I believe, six months, a settlement of about 6 in was recorded. Then we took the preload off and constructed the hump tunnel.

The computer building is of steel construction. This was necessary because we could expect, in this location, to get settlement and we will have to do some adjusting to keep the building level.

We also erected a retarder tower. It really is one of the items that was built into the yard just in case. There is nothing that actually needs to be run from the retarder tower. If our automatic controls went off, with 90 tracks in constant operation and 6,000 cars a day going over the hump, it would be absolutely impossible for an operator to run the hump manually. He might be able to run it at 2,000 cars a day. That is about the best he could do. The only reason we put the tower in was in case we happened to get a failure.

During the construction period two through routes were kept in full operation.

Gentlemen, that is about it for the A. E. Perlman yard. If there are any questions I would be glad to answer them.

QUESTION: Are there two scales on the hump?

MR. POPMA: Yes, there are two scales for the purpose of operating the computer. There is no scale to weigh the car. They are for the computer only. Any other questions?

Thank you, gentlemen. (Applause)

(Mr. Popma showed colored slides to illustrate his address, none of which is reproduced herein.)

PRESIDENT HUTCHESON: Thank you, Mr. Kellogg. We appreciate the efforts of yourself and the members of your committee on our behalf.

Mr. Popma, we want to thank you for that excellent presentation on the activities of the Penn Central in connection with its new Perlman Yard. We appreciate your efforts and continued support of AREA activities.

In his introduction, Mr. Kellogg did not say that Mr. Popma is a newly elected director of our Association. But he is, and we are delighted to have him in that capacity.

Mr. Kellogg, your committee is now excused with the thanks of the Association.

President Hutcheson: Gentlemen, this concludes the afternoon session. We thank you for your attendance and hope that you have gained much from the deliberations and discussions at this session of our convention.

I have just been informed that up to the present time registration at the convention is 3,225.

Our convention is now adjourned until 9 o'clock in the morning. The committees which will report tomorrow will be those important ones which work on matters related to the track and its component parts. Three interesting and timely special features are to be presented. The first report will be that of Committee 31—Continuous Welded Rail here in this room. I hope to see you all in the morning.

(The meeting recessed at 5 o'clock.)

Morning Session, March 21, 1968

(The meeting reconvened at 9 o'clock with President Hutcheson presiding.)

President Hutcheson: Good morning, gentlemen. Will the final technical session of our 1968 convention please come to order? There are three special features to be presented with the technical reports.

Your attention is called to the closing business session which will be convened immediately following the technical session this morning and we hope that a large number of you will find it possible to stay here to witness the installation of the officers and the other business of the Association which will be conducted at that time.

This morning's general technical session will be conducted by Harry M. Williamson, AREA vice-president and chief engineer system, Southern Pacific Company, San Francisco, Calif.

(Mr. Williamson assumed the chair.)

Discussion on Continuous Welded Rail

(For report, see Bulletin 612, pages 573–618)

Vice President Williamson: The first committee to report at this session is Committee 31, Continuous Welded Rail, the chairman of which is C. W. Wagner, engineer of tests, Canadian National Railways, Montreal, Que.

Since Mr. Wagner and his committee are already in place on the platform, I will immediately turn over the microphone to him, with only this added remark: if you desire to comment or ask questions in connection with any portion of the committee's presentation, please stand, address this chair, state your name and business affiliation clearly and then proceed.

Chairman C. W. Wagner: Mr. vice president, members and guests: the report of Committee 31—Continuous Welded Rail, appears in Bulletin 612, pages 573 to 618.

Assignment 6—Welding Second-Hand Rail

Chairman Wagner: Your committee reports on Assignment 6—Welding Second Hand Rail. The report will be given by Subcommittee Chairman W. E. Roberts, engineer of track, Chicago Rock Island & Pacific Railroad. Mr. Roberts.

W. E. Roberts: Mr. Chairman, members and guests: Subcommittee 6 has developed recommendations regarding Inspection and Classification of Second-Hand Rail for Welding. Our committee wishes to thank each person who answered our questionnaires on the subject to enable us to complete our work.

Other information was obtained from inspection of rail welding sites and observation of actual practices on various railroads. Our recommendations were submitted as information in Bulletin 612 and in our next report we will propose them as Manual material. We solicit your written comments.

(Mr. Roberts then read the report on "Inspection and Classification of Second-Hand Rail for Welding" printed on pages 617 and 618 of Bulletin 612.)

Chairman Wagner: At this time I would like to introduce the chairmen of the other subcommittees:

A. H. Galbraith, welding engineer, Santa Fe, chairman of Subcommittee 1—Fabrication.

R. E. Frame, chief engineer, Southern Pacific Company, Texas and Louisiana Lines, chairman of Subcommittee 3—Fastenings.

J. R. Rymer, division engineer, Baltimore & Ohio, chairman of Subcommittee 4—Maintenance.

C. W. Law, staff engineer, Federal Railroad Administration, chairman of Subcommittee 5—Layout of Fixed and Portable Welding Plants.

O. E. Fort, chief engineer of the Frisco, and chairman of Subcommittee 2, could not be with us.

Our special feature this morning is an illustrated address on "Thermite Welding Practices of Rail in the United States." Our committee is most fortunate in having within our membership an expert in the field of thermite welding. I am referring to K. H. Kannowski, formerly metallurgical engineer with the AAR and presently research engineer of the Illinois Central Railroad.

Gentlemen, it gives me great pleasure to call on Mr. Kannowski at this time.

Thermite Welding Practices of Rail in the United States

By K. H. KANNOWSKI

Research Engineer, Illinois Central Railroad

K. H. Kannowski: The advent of continuous welded rail has brought with it several problems, one being the weak link introduced in welded rail where two ribbons are joined with a standard rail joint; another is devising effective means to repair damaged or defective rails in the ribbons without resorting to standard rail joints, which defeat the purpose of ribbon rail. Recently in the United States the alumino-thermic welding method for joining the ribbons has become practical. Improved thermite welding methods have been introduced which produce rail joints meeting the quality of electric-flash butt-welded rail joints and oxyacetylene pressure butt welded rail joints.

The thermite method of joining rail is not new. It was developed by Dr. Goldschmidt in Germany in 1900. It has been used extensively since then all over the world except in the United States. This process was also developed in France under the name of Boutet, as it is now known and used in the United States. The Goldschmidt process came to the United States prior to World War I and became known as the Thermex Metallurgical process. The Goldschmidt process again came to the United States prior to World War II as the Exomet process and, as such, is in use. The Orgotherm process started recently in this country is the original Goldschmidt thermite process.

The alumino-thermic or thermite reaction is defined in the ASM handbook as a strongly exothermic self-propagating reaction, where finely divided aluminum reacts with a metal oxide. A mixture of aluminum and iron oxide produces sufficient heat to weld steel, the filler metal being produced in the reaction. It is of interest at this time to mention that the spelling *Thermit* is a trade name owned by the Thermex Metallurgical Company in this country. The generic name for the process is thermite or alumino-thermic.

The reaction takes place at 5,000 F and produces a filler metal at 3,500 F which, in entering the rail gap, welds and fuses the rail ends. This filler metal is pure iron with a low hardness, which has to be enriched with alloys and high carbon steel to produce a rail-quality filler metal.

In all of the processes, this reaction takes place in a crucible. When the reaction is completed, the metal is either tapped manually as in the European processes or is self-tapping as in the United States processes. In all cases, the metal is tapped into prefabricated molds which are disposable. The separate crucible, preheaters, clamps, tapping devices and hand tools are the equipment of the European processes. The United States-developed processes have disposable shell molds with reacting chambers and very few tools with their packaged unit welds. Even the preheating is built in the shell mold in the nature of an exodhermic material. In another case preheating is done by the first metal tapped running over the weld faces. This metal after changing its heat content could not serve as filler weld metal. It is discarded in a metal sump.

This process originally produced a weld sufficiently strong for use in most countries of the world but which did not meet our requirements. In recent years, however, the Orgotherm method has produced welds which ran consistently 2,000,000 cycles without failure in rolling-load tests at the AAR research center, meeting the United States requirement. Since then, Thermex Metallurgical and Boutet welds have met this standard and Exomet welds have approached it.

I am going to show a film on the Thermex Metallurgical, the Boutet and the Orgotherm processes. You will note the European procedures in producing the Orgotherm and Boutet field welds require considerable equipment. In this country a disposible package with the least amount of equipment has been developed to produce field welds by the Thermex Metallurgical and Exomet processes.

(The film was then shown, with commentary by Mr. Kannowski, after which Mr. Kannowski concluded as follows:)

Mr. Kannowski: The basic requirement for a good thermite weld, of course, is good alignment of the rail ends, and removal of all dirt, grease, and loose oxides from the welding environment. The gap between the rail ends must be sufficient to permit a fast metal flow. Preheating must be done to produce good fusion and a failure-free weld. In the processes shown to you, preheating varied from none to a temperature of 900 to 1800 F.

The quality of the weld depends on the weld face being square to the running surface of the rail. The gap between the welding surfaces should be at least ⅝ inch and should be increased to ⅞ inch with larger rail sections. The size of the gap should be such as to promote a good preheat and a rapid metal flow. The gap can be either flame or saw cut. All burrs on the edge of the gap must be removed. Loose oxides on the weld surfaces should also be removed. The dirt and overflow on relay rail must also be removed. The rail ends should be lined with a slight amount of crown in order to produce a flat-welded running surface after cooling and grinding. The rail ends must be preheated sufficiently to promote good fusion with the weld metal, or the weld metal must be hot enough to fuse with the rail ends. The weld metal should be of a hardness to match that of the rail steel, 250 to 280 B.H.N.

(Applause)

Chairman Wagner: Thank you, Mr. Kannowski for your very interesting presentation.

Mr. Vice President, this concludes our report and also brings to an end my term as chairman of Committee 31. I wish to publicly thank my committee members, especially my subcommittee chairmen, for their support and cooperation.

Our new vice chairman is B. J. Gordon, engineer maintenance of way, Penn Central. Mr. Gordon, would you please stand?

Our new chairman is B. J. Johnson, regional assistant chief engineer, C&O–B&O. Unfortunately, he could not be here today. Mr. Johnson is a very capable man, and I am sure that the work of this committee will improve under his leadership.

Thank you very much.

Vice President Williamson: Thank you, Mr. Wagner, for the efforts of yourself and the members of your committee this past year, and for that interesting and timely presentation.

Mr. Kannowski, we appreciate your continued efforts on our behalf, and thank you for those most interesting motion pictures and your comments.

Mr. Wagner, we appreciate the able and dedicated leadership you have given to Committee 31 for the past three years. As you are relieved of your responsibilities as chairman, we are pleased to welcome Mr. Johnson as your successor, and Mr. Gordon as the new vice chairman of your committee. We are satisfied from their past performances, that under their direction the good work of Committee 31 will continue.

Unfortunately, as you said, Mr. Johnson is unable to be here. We wanted to present him with a gavel symbolic of his chairmanship, and in his absence we will see that the gavel is sent to him. The gavel bears the inscription:

"Mr. B. J. Johnson, Chairman AREA Committee 31, 1968–1970."

Your committee is now excused, Mr. Wagner, with the thanks of this Association.

Discussion on Rail

(For report, see Bulletin 612, pages 619–709)

Vice President Williamson: The second report of this session will now be given by Committee 4—Rail, the chairman of which is C. C. Herrick, engineer track maintenance, Penn Central, New York.

Mr. Herrick, you may now proceed as soon as the members of your committee are in place.

Chairman C. C. Herrick: Vice President Williamson, members and guests: The Rail Committee, through no one's fault, has had three chairmen in two years, so we have been a little bit slow in getting organized. We think we are now organized, however, and are ready to run.

I would like at this time to introduce our vice chairman and subcommittee chairmen.

J. B. Clark, chief engineer, L&N, is vice chairman, and chairman of Subcommittees A—Recommendations for Further Study and Research, and Assignment 1—Revision of Manual.

I am chairman of Subcommittee 2—Collaborate with AISI Technical Committee on Rail and Joint Bars in Research and Other Matters of Mutual Interest. The question is raised sometimes as to just what the Joint Contact Committee is. The Joint Contact Committee consists of the members of Subcommittee 2 of the Rail Committee, and representatives from the rail producing mills, who are members of the AISI. The committee meets at least once, sometimes twice, a year to try to iron out the problems encountered in producing rail.

D. T. Faries, chief engineer, Bessemer & Lake Erie, is chairman of Subcommittee 3—Rail Failure Statistics.

R. C. Postels, assistant chief engineer maintenance of way, Soo Line Railroad, is chairman of Subcommittee 4—Rail End Batter.

The chairman of our new Subcommittee 5—Rail Chemistry, is Kurt Kannowski, research engineer, Illinois Central Railroad.

Subcommittee 6 on joints bars is headed by W. D. Almy, assistant division engineer, B&O.

The chairman of Subcommittee 7 on the metallurgical effect of rail cropping methods is S. H. Barlow, engineer maintenance of way, Northern Pacific Railway.

C. F. Parvin, engineer maintenance of way, Penn Central, is chairman of Subcommittee on Causes of Shelly Spots and Head Checks in Rail.

Subcommittee 9—Standardization of Rail Sections, is headed by E. H. Waring, chief engineer, Denver & Rio Grande Western Railroad.

We also have another new subcommittee, No. 10, which is chairmanned by W. T. Hammond, engineer of standards, Penn Central, who could not be here this morning. His subject will be Effect of Heavy Wheel Loads on Rail.

We also have a new secretary, Vic Hall, office engineer, Atchison, Topeka & Santa Fe. Our former secretary, Cliff Morgan, is retiring.

We have no technical report except what is in Bulletin 612, but would like to tell you very briefly what the Rail Committee is trying to do. We have been charged by the Board of Direction to see what we can do about getting longer rail from the mills. That subject is being handled by Subcommittee 2 and the Joint Contact Committee.

Last fall the Joint Contact Committee went to Montreal and viewed continuous castings of steel at Dosco. It was a very interesting and informative sight and may mean something in the future of longer rail.

The Joint Contact Committee also had a 7:00 am breakfast meeting this morning with an attendance of almost 100 percent.

Our February meeting was held at Pueblo, Colo., where we toured the CF&I Steel Corporation's rail mill and the Linde rail hardening plant. It was very enjoyable and educational, and we wish to thank the people from CF&I and Linde for their fine cooperation.

This fall the Rail Committee will probably meet in conjunction with or immediately after the Roadmasters Convention, and will visit the Gary rail mill of United States Steel.

Since roughly a million tons of rail are rolled a year, and well over a hundred million dollars are spent each year by the U. S. railroads for rail, we of the Rail Committee urged that the top officers of the railroads get themselves interested in the subject of rail; we think that the effect would be very beneficial on the entire industry.

I would like to point out that the February Bulletin includes an interesting chart, "Moments In Railway Rail," which was published for your use and information. It was prepared by G. C. Martin at the University of Illinois.

That concludes the Rail Committee's report. Thank you.

Vice President Williamson: Thank you for that report, Mr. Herrick, and for the efforts of your committee this past year. As you explained to the Association, there has been quite a turnover in the chairmanship of Committee 4 in the last year or so. Consequently, you have not been officially presented with a gavel to conduct the business of your committee. I would like to take this opportunity to do so now, and to wish you the very best of success in carrying on the very important work of the Rail Committee.

It gives me a great deal of pleasure to present you with this gavel.

(The gavel was presented to Mr. Herrick.)

(Applause)

Vice President Williamson (continuing): Mr. Herrick, you and your committee are excused with the thanks of the Association.

Discussion on Ties and Wood Preservation

(For report, see Bulletin 612, pages 531–544)

Vice President Williamson: We will now hear from Committee 3—Ties and Wood Preservation. The chairman of this committee is K. C. Edscorn, purchasing agent, Missouri Pacific Railroad. Mr. Edscorn, the microphone is yours.

Chairman K. C. Edscorn: Mr. Vice President, members and guests: The report of Committee 3 is published in Bulletin 612, pages 531 to 544, incl.

I regret to report, since our last meeting the death of Harry Duncan, retired superintendent of timber preservation and Member Emeritus of Committee 3, on October 24, 1967.

Work has progressed on some phase of all six of our assignments during the year, and we would like to make a short statement on two of them.

Assignment 1—Revision of Manual

Chairman Edscorn: Work on this important assignment has been carried on under the very able direction of C. S. Burt, assistant to vice president, Purchases and Stores, Illinois Central Railroad. For those of you who do not already know: Mr. Burt retired on December 31, 1967. A few weeks later, while visiting his daughter in Nashville, Tenn., he suffered a heart attack. After a short stay in the hospital, he was released and has remained in Nashville to recuperate. The latest report is that the Burts should be returning to Chicago within a few weeks.

Assignment 2—Cross and Switch Ties

Chairman Edscorn: The chairman of this subcommittee is E. M. Cummings, regional assistant chief engineer, C&O–B&O, who was unable to be present today.

Assignment 3—Wood Preservatives

Chairman Edscorn: Subcommittee Chairman W. W. Barger, chief inspector, Tie and Timber Treating Department, Santa Fe Railway, will present a short statement on this assignment. Mr. Barger.

W. W. Barger: Mr. Vice President, Mr. Chairman, members of the American Railway Engineering Association and guests:

Under Assignment 3, Wood Preservatives, there are two instructions, as follows:

(a) Keep up-to-date current specifications for preservatives.

(b) New preservatives.

Under Instruction (a) your committee has made changes in the specifications in Chapter 17 of the Manual in order to bring them up-to-date with the same specifications of other national organizations. Some of the changes are editorial, others are minor that help to more clearly describe the preservative.

These preservatives are listed on Page 338 of the Manual Recommendation Supplement to Bulletin 610, and revised versions of the preservatives are printed in that Bulletin starting at the bottom of page 338.

Your committee has also deleted two salt preservatives due to their decline in use. These preservatives are copperized chromated zinc chloride (CuCZC) and chromated zinc arsenate (CZA).

Under Instruction (b), your Committee would like to call to your attention a new preservative, solubilized copper-8-quinolinolate. This preservative has a limited use. It is approved specifically for the treatment of wood which might come in contact with foodstuffs. The specification is printed on page 342 of the Supplement to Bulletin 610.

Assignment 4—Preservative Treatment of Forest Products

Chairman Edscorn: The subcommittee chairman is L. C. Collister, manager of treating plants, Santa Fe Railway. I would like to recognize Mr. Collister.

Suffice it to say, with regard to this assignment, that here have been appropriate changes made in the treating specifications to accommodate changes that were made in the list of preservatives recommended for use.

Assignment 5—Service Records of Forest Products

Chairman Edscorn: The chairman of this subcommittte is J. T. Slocomb, industrial forester, B&O Railroad, who was unable to be present today.

Assignment 6—Collaborate With AAR Research Department and Other Organizations in Research and Other Matters of Mutual Interest

Chairman Edscorn: The chairman of this subcommittee is P. D. Brentlinger, forester, Penn Central, who was unable to be with us today.

Chairman Edscorn: (continuing): At this time I would like to call upon L. W. Boyer, second vice president of the Railway Tie Association, and chairman of its Wood Tie Promotion Committee, who would like to make an announcement regarding the test section on the Chicago & North Western, which has been set up as a cooperative study between the AAR Research Center and the Railway Tie Association. Mr. Boyer.

L. W. Boyer: Thank you, Mr. Edscorn: I don't know how many of you are aware of the cooperative studies that have been going on between the AAR Research Center and the Railway Tie Association. It has been my pleasure for the past three years to chairman the RTA's Committee on Wood Tie Promotion. A lot of work and a lot of money has been spent on this research, and we have finally gotten to the service testing stage.

If I recall correctly, unfortunately I did not bring the proper papers, there are 20 sections of test track in the Chicago & North Western, in the general area of Des Plaines, Ill. This track contains specially doweled ties, and has some rather, shall I use the word "exotic," or at least different, tie spacings. These ties were placed in track last fall, and it is our intention to have an on-site inspection of this area. It is hoped that we can take you to the test section the first week of May. This is the date we are shooting for.

The AAR Research Center and the Railway Tie Association would like to extend to each of you an invitation to visit this section on whatever date might be finally set.

Again I would say that we are shooting for the first week in May. Proper notices will go out to various railroad people, purchasing and engineering specifically, and we shall announce it also through other media to get the word to all of you. Thank you very much.

Chairman Edscorn: Thank you, Mr. Boyer. I am sure that many railroads will want to have a representative look at this test section.

I would like at this time to gratefully acknowledge and thank the chairmen of our subcommittees for the work they have accomplished this past year. Without their efforts, our assignments could not be carried out.

Mr. Chairman, this concludes the report of Committee 3—Ties and Wood Preservation.

Vice President Williamson: Thank you, Mr. Edscorn, for that report, and for the valuable service you and your committee have rendered to the Association this year.

Mr. Edscorn, your committee is now excused with the thanks of the Association.

Discussion on Roadway and Ballast

(For report, see Bulletin 612, pages 511–529)

Vice President Williamson: The next committee to report will be Committee 1—Roadway and Ballast, the chairman of which is C. E. Webb, engineer of tests, Southern Railway System. Mr. Webb, you may proceed when your committee is ready.

Chairman C. E. Webb: Mr. Vice President, members and guests:

During the past year, Committee 1 held two regular meetings. Its complete report is published in Bulletin 612, February 1968, pages 511 through 529. Editorial revisions to the Manual are reported in Supplement to Bulletin 610, December 1967.

The committee wishes to report the death of one of our Members Emeritus, Col. B. H. Crosland, retired chief engineer, St. Louis–San Francisco Railway, and former chairman of this committee.

F. N. Beighley, roadway engineer, St. Louis–San Francisco Railway, will present a memoir to him. Mr. Beighley.

(Mr. Beighley then read the following memoir in honor of the late Col. Crosland.)

Colonel Benjamin Harold Crosland
1891-1967

Benjamin Harold Crosland, retired chief engineer, St. Louis–San Francisco Railway, and Life Member of AREA, passed away at his home at Springfield, Mo., on December 27, 1967, of acute coronary thrombosis at the age of 76. Burial was in the National Cemetery, Ft. Scott, Kans. He is survived by his widow, Nelle Ruth; a daughter, Mrs. Eleanor Bodwell of Golden, Colo; and a son, Warren T. of Costa Mesa, Calif.

Col. Crosland was born in Rochester, N. Y., on July 9, 1891, was educated in the public schools of Rochester, and attended Cornell and Valparaiso Universities, earning B.C.E. and C.E. degree. He was a prolific reader throughout his entire life.

His first railroad experience was that of an axeman on the Canadian Pacific during the summer of 1908, in which capacity he continued to work throughout his college vacations. After graduation from Valparaiso University in 1914, he went to Kansas City and did engineering work for several firms, one of which was Parker–Washington Construction Company. In 1915, he went with the Interstate Commerce Commission and worked on railway valuation until 1917 when he was called to service in World War I in the 70th Engineers, U.S. Army Railway Construction. After discharge, in 1919, he returned to the ICC, again working on railway valuation. In 1920 he hired out to the Frisco at Springfield, Mo., as transitman. He advanced through various engineering and maintenance of way positions to that of division engineer in 1938 at Ft. Scott, Kans. In 1941 he was called upon by General Carl R. Gray to form the Reserve Headquarters Military Railway Service and serve as its chief engineer, with the rank of lt. colonel, On April 15, 1942, he was inducted into active duty with rank of colonel in the Transportation Corps and shortly thereafter went to North Africa. For 37 months he had charge of railway rehabilitation and maintenance, using American, British and French crews, in North Africa, Sicily, Italy, Southern France, Southern Germany, Belgium and Luxemberg. For one month he commanded all military railway service troops in the European Theatre, numbering upwards of 15,000 men.

Colonel Crosland was decorated with World War 1 Victory Medal, World War II Victory Medal, Legion of Merit Award, French Croix de Guerre with Palms, French Croix de Guerre with Silver Star, Italian Order of Crown with Gold Crown lapel button, Meritorious Unit Award with two clusters, European–African–Middle Eastern Service ribbon and American Service ribbon with 7 battle stars. He was separated from the Army July 6, 1946, and returned to the Frisco, assuming the position of assistant chief engineer at Springfield. He was advanced to chief engineer maintenance of way January 1, 1956, and became chief engineer January 1, 1957, serving in that capacity until he retired July 3, 1961.

Colonel Crosland was a man of ability with a broad background of experience. He was instrumental in organizing district gangs with which to do out-of-face track maintenance, using mechanical tools and machines. Young engineers were his primary interest in "on-the-job" training for future railroad supervisory personnel. He had a great love for the railroad and his boot prints are embedded many places along the right-of-way of the Frisco.

Colonel Crosland joined AREA in 1941, being assigned to Committee 1—Roadway and Ballast. Through his diligent and untiring work on subcommittees, he became vice chairman in 1950, and chairman of the committee, 1953–1956. He was a member of the AREA Nominating Committee in 1959. After retirement from railroad service, he maintained a keen interest in the work of the committee and was elected Member Emeritus in 1965. He became a Life Member of AREA in 1966. His activities with AREA and Committee 1 were very closely related to his railroad interest, that of roadbed stabilization. The Colonel was quite an avid cigar smoker, and committee members would know they were in for a long and hard session when he would pile up the cigars in front of his place at the conference table. His absence from the committee will be greatly felt because of his poise and his proficiency in maintaining continuity during the deliberations.

In addition to his activities in AREA, he maintained membership in the American Legion, Society of American Military Engneers, Reserve Officers Assocation, Military Order of World Wars, Roadmasters and Maintenance of Way Association, and the Mississippi Valley Maintenance-of-Way Club. He was an ardent member of Christ Episcopal Church in Springfield.

The Colonel was warmly esteemed by those who had an opportunity to be associated with him, and genuinely respected for his contributions in the field of railway engineering and maintenance.

F. N. Beighley, *Memorialist.*

Chairman Webb: In the interest of conserving time, I will only briefly review our assignments. However, it is appropriate to recognize the diligence and effort of the officers of our Committee, and I would like to introduce them as each assignment is mentioned.

Assignment A—Recommendations for Further Study and Research

Chairman Webb: M. B. Hansen, area engineer, Canadian National Railways, is chairman of Subcommittee A and vice chairman of Committee 1.

Assignment 1—Revision of the Manual

CHAIRMAN WEBB: L. J. Deno, maintenance engineer, Chicago & North Western Railway is chairman of this subcommittee.

Assignment 2—Physical Properties of Earth Materials

CHAIRMAN WEBB: Study is in progress to consolidate and improve Manual material on this subject. F. L. Peckover, engineer of soils and foundations, Canadian National Railways, is chairman of this subcommittee.

Assignment 3—Natural Waterways

CHAIRMAN WEBB: Study is in progress to revise and update present Manual material. N. E. Whitney, Jr., drainage engineer, Illinois Central Roailroad, is chairman of this subcommittee.

Assignment 4—Drainage and Culverts

CHAIRMAN WEBB: A preliminary report on new types of drainage pipe is published in the Bulletin. W. M. Dowdy, division engineer, Chesapeake & Ohio Railway, is chairman of this subcommittee.

Assignment 5—Specifications for Pipelines for Conveying Flammable and Non-flammable Substances

CHAIRMAN WEBB: A report as information is published in the Bulletin. Tests on uncased pipeline crossings have been completed by the research staff of the AAR Research Center and are being jointly reviewed by the AAR staff and the Batelle Memorial Institute. Specifications for pipeline crossings have been quite controversial, and it is the intent to preserve the right of individual railroads to establish independent controls as found necessary to insure safe operation of railroads. E. E. Farris, assistant engineer, Chicago Burlington & Quincy Railroad, is chairman of this subcommittee.

Assignment 6—Roadway: Formation and Protection

CHAIRMAN WEBB: A report is published as information in the Bulletin on the stabilization of the roadbed with lime. This important work is being continued. G. F. Nigh, assistant engineer, Norfolk & Western Railway, is chairman of this subcommittee. He is also secretary of Committee I.

Assignment 7—Tunnels

CHAIRMAN WEBB: Study is in progress to revise and improve the Manual materials on tunnels. M. W. Cox, division engineer, Louisville & Nashville Railroad, is chairman of this subcommittee.

Assignment 8—Fences

CHAIRMAN WEBB: Manual material will be reviewed for any appropriate changes. J. B. Wackenhut, assistant engineer, Bessemer & Lake Erie Railroad, is chairman of this subcommittee.

Assignment 9—Roadway Signs

CHAIRMAN WEBB: This subcommittee is keeping abreast of new developments in roadway signs. R. D. Baldwin is chairman of this subcommittee.

Assignment 10—Ballast

Chairman Webb: A progress report on this assignment is presented in the Bulletin. It is planned ultimately through a research program to provide realistic and workable specifications for railroad ballast. E. L. Robinson, Jr., Superintendent, Haystock Mountain Development Company, Atchison, Topeka & Santa Fe Railway, is chairman of this subcommittee.

Assignment 11—Control of Vegetation

Chairman Webb: A preliminary report is published in the Bulletin. This subcommittee is working on types and characteristics of commonly used herbicides; spray equipment, techniques and practices; and asphalt impregnated with herbicide for erosion control. D. H. Yazell, engineer of vegetation control, Atchison, Topeka & Santa Fe Railway, is chairman of this subcommittee.

Chairman Webb (continuing): For its special feature this year, our committee is most fortunate in having Dr. R. M. Hardy, dean of engineering, University of Alberta, make a presentation on stress distribution in track structure, a most timely subject.

Dr. Hardy obtained his Bachelor of Science degree in civil engineering from the University of Manitoba and Master of Science degree in civil engineering from McGill University. With later graduate studies at the University of Michigan, Harvard University and University of Manitoba, he was awarded a Doctor of Science degree.

Dr. Hardy is the author of some 60 technical papers and discussions in the field of soil mechanics and foundation engineering, and is a member of a number of professional and engineering societies, among them, Fellow–Royal Society of Canada, Engineering Institute of Canada and American Society of Civil Engineers.

During the past 25 years, his professional practice has been almost entirely as a specialist in the field of foundation engineering, earth structures and special soil problems concerned with the design, location and performance of highways, railways, and pipelines. For the past five years Dr. Hardy has held the post of Dean of Engineering, University of Alberta.

It is with pleasure that I now call on Dr. Hardy.

Stress Distribution in Track Structure

By DR. R. M. HARDY

Dean of Engineering, University of Alberta

The study we are reporting on today was made on the Sangudo Subdivision in the Mountain Region of the Canadian National Railways in Western Canada. The line is 103 miles long and runs from Edmonton to Whitecourt in the Province of Alberta.

The first 32 miles are on the old Canadian Northern line built in 1911 using 80-lb rail. The extension to Whitecourt was built in the period 1918–21. It was designed for an E 40 loading, and was built using elevating graders, bottom-dump wagons and teams and fresnos; 60-lb rail was used.

The grade as it existed in 1963 was narrow, with steep side slopes and shallow ditches.

The area has been glaciated in its geological history, and geologists postulate that the end of the last glaciation was only 9,000 to 10,000 years ago.

Fig. 1 shows the general surficial geology over the length of the line. For the first 60 miles it passes mainly through ground moraine or hummocky moraine left by the last glaciation. The predominant soil in this area is a silty clay till of medium plasticity. It has been over-consolidated by glacial action, which by definition means that it has been subjected to much greater over-burden pressure in its geological history than presently exists on it. It currently exists in a state of rebound. The natural moisture contents generally are close to the plastic limits, and in its intact state the till is a very competent material. Generally the roadbed in this section has given reasonably good performance over the years.

From about Mile 60 to 90 the surficial soils are geologically recent glacial lake deposits. These are highly plastic clays and silty clays, with liquid limits up to about 90. The liquidity indices are generally low, but in seepage zones they have been found to run as high as 0.8. They are moderately sensitive, showing a sensitivity of about 2. The intact shearing strengths vary widely within a range of about 400 to 2,000 lb per sq ft. Roadbed stability problems have existed in this section ever since the line was built.

From mile 92 to 99 the line drops down 167 ft into the valley of the Athabasca River. The location is on side hill on a maximum grade of 0.5 percent. The river valley is cut into the bedrock deposits. These are predominantly shales and sandstones with some coal and gravel. The shales and standstones are of poor quality. They have been heavily over-consolidated, but they are fissured and fractured, and some of the shales tend to revert to highly plastic clays under reduced confining pressures and availability of water. There are numerous seepage zones in any given soil profile. In common with many other river valleys in western Canada, this valley bank has formed by sliding and sloughing, with many movements being deep-seated. Many portions of the bank are in a delicate state of stability. Roadbed problems have always existed in this section.

The surface drainage along the whole length of the line is poorly developed, and therefore over numerous stretches the surface cover is muskeg (peat), with the thickness of organic mat in some cases being as much as 7 ft. In the original construction the roadbed was built directly on top of the muskeg. The practice at the time was to place the initial mat of fill on the muskeg with wheelbarrows.

It is characteristic of all soils in the general area of this line that the clay fractions have significant percentages of montmorilonite clay mineral. These soils therefore all have swelling tendencies in varying degrees.

Traffic on the line was never heavy, and in fact became very scarce in later years up to 1962. E 40 loadings were seldom exceeded. However, in November 1962, a natural gas scrubbing plant in the Whitecourt area generated a new type of traffic in the form of sulphur hauled in tank cars. These have axle loads of 60,000 to 66,000 lb, and are hauled with 6-axle diesels having 40,000-lb axle loads. Thus the new traffic increased the wheel loads by some 50 percent. In addition the density of traffic was substantially increased, and each loaded train applied a greater number of rapid repetitions of the maximum axle load than had occurred before 1962.

The line satisfactorily carried the heavier loadings during the winter of 1962–63 when the embankments were frozen. However in the spring and summer of 1963 severe deterioration of the roadbed occurred. It was most pronounced in the area

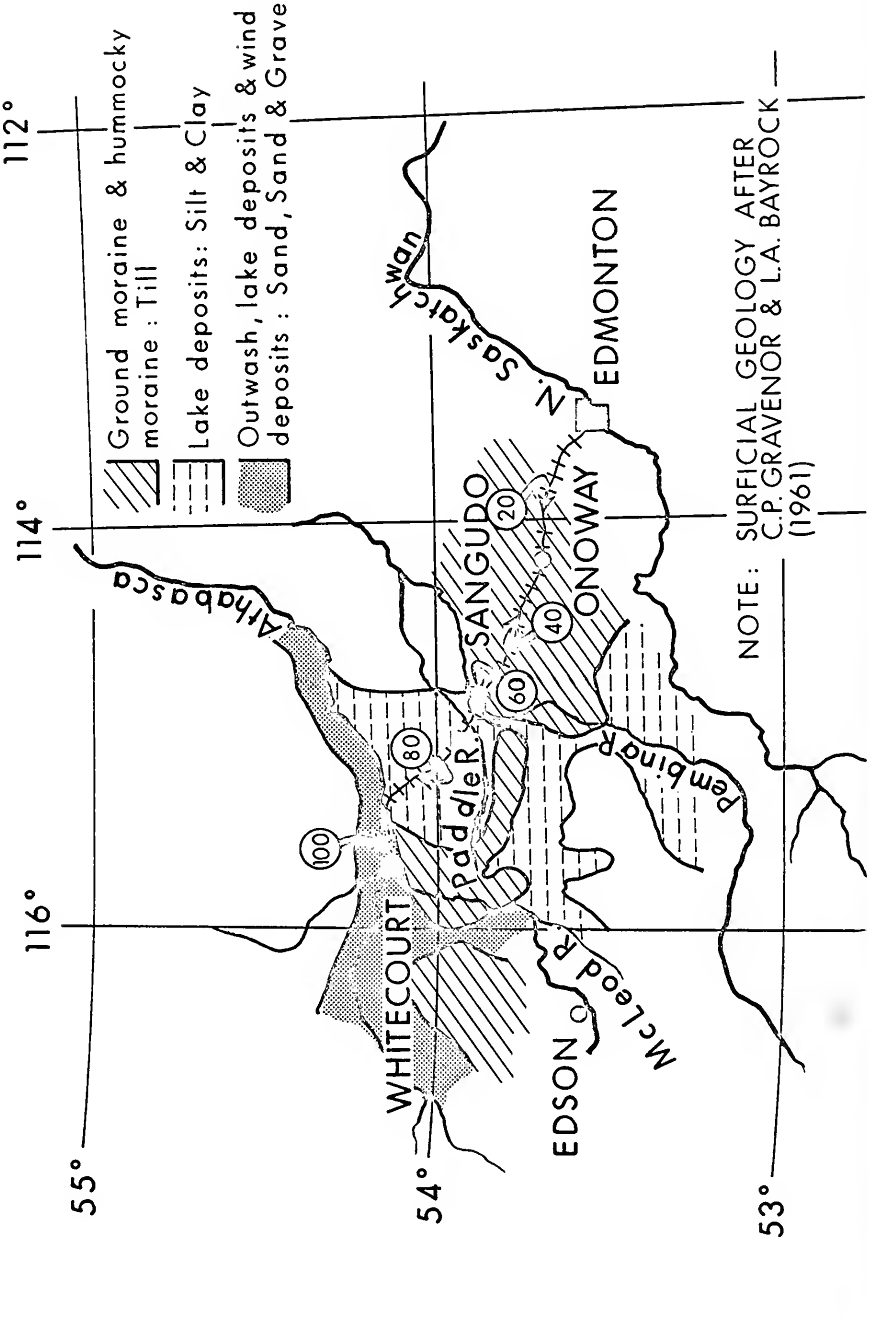

Ground moraine & hummocky moraine : Till
Lake deposits: Silt & Clay
Outwash, lake deposits & wind deposits : Sand, Sand & Gravel
112°
114°
116°
55°
54°
53°
N. Saskatchewan
EDMONTON
SANGUDO
ONOWAY
Athabasca
Paddle R.
Pembina R.
WHITECOURT
EDSON
McLeod R.
20
40
60
80
100
NOTE : SURFICIAL GEOLOGY AFTER C.P. GRAVENOR & L.A. BAYROCK (1961)

Fig. 1

of clay soils from Mile 60 to 99 and in muskeg sections. Four major types of instability developed:

First, bulging of embankment side slopes occurred to a much greater degree than in the previous history of the line, and at several such locations sloughs developed. The height of fills involved ranged from only 5 or 6 ft to about 20 ft.

Second, bearing failure below the ties, as evidenced by heaving of the ballast between and at the ends of the ties, occurred at many locations both in cuts and fills. However, at all of these locations the ballast was thin and of poor quality, and the fills were clay soils rather than tills.

Third, the incidence of joint bar failures increased greatly, creep occurred in the rails, and the maintenance of track alinement became much more difficult.

Fourth, the general stability conditions on the sidehill location from Mile 92 to 99 deteriorated extensively.

The corrective measures undertaken involved the usual conventional methods of:

(a) Improvement of the drainage by widening and deepening the ditches.

(b) Providing increased confining stress for the embankments by widening and flattening the slopes by means of berms.

(c) Increasing the thickness of ballast and improving its quality.

(d) Increasing the weight of rail to 100 lb.

Detailed studies were made at several major slide areas. These involved drilling, sampling and soil testing programs and stability analyses. However for the section from Mile 60 to 99, where clay soils are predominant, an attempt was made to assess the conditions in terms of the minimum strength to which the soils deteriorate in their present environment. The major environmental factors include the original density of the soil in the fill, climatic weathering factors including freezing and thawing, drainage conditions adjacent to a particular track structure, and weight and frequency of train loads. For this approach we had a number of locations where the conditions had developed to failure, or alternatively were in a delicate state of equilibrium.

Thirteen such locations were analyzed in some detail. One of these was in a cut, and the remainder were fills varying in height from 7 to 20 ft. The preliminary work indicated that in all cases the soils involved were highly plastic clays, and they were saturated. The weight of the embankments themselves produces a continuing gravity loading, but the train traffic induces a transient loading with a rapid number of repetitions of maximum stress in the soil. Under these conditions it was considered that the embankment stabilities would best be assessed in terms of total stresses and undrained soil strengths. In terms of soil mechanics jargon this means that the soil was considered to act as a $\phi = 0$ material, rather than that effective stress concepts applied. The results of these analyses are shown in Table 1.

It will be noted that the minimum soil shearing strengths were estimated to be within the range of 400 to 560 lb per sq ft. The average maximum shearing stresses induced by the fills themselves, on the most critical path of failure, ranged from 270 to 300, while the total for the fill plus the E 40 loading ranged from 389 to 432, and with the E 66 loading from 463 to 497 lb per sq ft. No allowance was included for impact. No very high degree of precision is claimed for these numerical values, but their relative values are remarkably consistent with the performance of the embankments over the history of the subdivision.

TABLE 1

SUMMARY OF SOIL STRENGTH AND SOIL STRESSES INDUCED BY VARIOUS LOADINGS (POUNDS PER SQUARE FOOT - SHEARING STRESS)

Min. Soil Strength	Stress From Fill	Fill Plus E-40 Load	Fill Plus E-66 Load
400 to 500	270 to 300	389 to 432	463 to 497

The E 66 loading increases the critical shearing stresses in the fills by about 70 percent as compared to the stresses due to the gravity forces of the fill materials. The increase is only about 20 percent as compared to the critical shearing stresses produced by the fill plus the E 40 loading, but this 20 percent increase was sufficient to increase the shearing stresses to the upper portion of the range in soil shearing strength.

These results were used in the upgrading program principally in the design of stabilizing berms.

Special attention was also given to the question of the ballast thickness that should be used in the upgrading program. In terms of the stability of the track structure a major function of the ballast, of course, is to spread the load from the ties to the subsoil. If the stresses transmitted exceed the ultimate bearing capacity of the subsoil a true or classical bearing failure occurs in the subsoil. This is manifested by an upheaval between ties and frequently also at the ends of the ties.

For a saturated cohesive soil subjected to rapid loading such as occurs from train loadings, semi-empirical relationships are available to estimate the ultimate bearing capacity of the subsoil immediately below the ballast in terms of the shearing strength of the subsoil. Under the E 66 loading, such an analysis gives a required shearing strength of 575 lb per sq ft. This exceeds the range of minimum soil shearing strengths shown in Table 1, and penetrometer tests on the in-situ soil at the location of a failure gave strength values of about 500 lb per sq ft. In contrast the required shearing strength for the E 40 loading is only 350 lb per sq ft, which indicates a factor of safety of 1.15 to 1.4.

On the basis of these considerations the following ballast thicknesses were recommended for the upgrading program:

Mile 0–60, for the till soils—18 inches
Mile 60–103, for the clay soils—24 inches.

The muskeg subsoils, however, present a different problem. Even if sufficient ballast is applied to prevent squeezing up between the ties, failure can occur by squeezing out of the muskeg below the fill. The most severe loading on the muskeg to induce this type of failure is the weight of the embankment mat plus the load from two trucks of adjacent cars or locomotives. The problem then is the bearing capacity of the muskeg under this loading system, or alternatively, the bearing capacity of soft clay which frequently occurs immediately below the muskeg. These considerations led to the recommendation of 36 inches for thickness of ballast in muskeg areas, with side slopes of the fill to be not steeper than 3:1.

The urgency of the upgrading program on the line raised the question as to whether the ballast could be improved sufficiently so that the performance of the track structure with the existing 60-lb rail would be comparable to what could be expected with 100-lb rail with more or less standard ballast thickness and quality. A rational answer to this problem was attempted on a theoretical basis. However because of the uncertainties in the values of the physical parameters and the boundary conditions in the mathematical model, it was decided to undertake a field test program.

The test program was laid out to assess the performance of the track structure in terms of the rail stresses, the deflection of the ballast and the deflection of the subsoil. Five variables were included, namely, weight of rail, thickness of ballast, density of ballast, quality of ballast with the performance of crushed gravel being compared to that for pit run gravel, and weight of traffic. The tests were run on a spur section at Mile 74 (at Mayerthorpe), over a length of 420 ft.

Fig. 2 shows the profile along the test section. It was divided into 6 sections. Sections 1, 2 and 3 were ballasted with loosely placed crushed gravel with the thickness being 9, 18 and 30 inches, respectively (measured to bottom of the ties). Sections 4, 5 and 6 were ballasted with loosely placed pit-run gravel of thicknesses 30, 18 and 9 inches, respectively. The ballast was built up in a shallow cut varying from 1½ to 3 ft.

Fig. 3 shows the soil conditions at the site as determined from 18 shallow test holes plus natural moisture contents on samples at the bottom of the excavation. The strength and modulus of deformation tests were run on samples with a confining stress of 10 psi. The soil was highly plastic clay of better-than-average quality for the glacial lake deposits from Mile 60 to 99. The liquid limits were generally within the range of 70 to 90, but the natural moisture contents were close to the plastic limits with the maximum liquidity index recorded being about 0.25.

Fig. 4 shows the grading of the two ballast materials.

Fig. 5 shows the arrangement of the instrumentation. Rail deflections were measured on the calibrated strips mounted on the sides of the rail using surveyor's levels on permanent mountings in three pits along the side of the test section. Ballast deflections were measured by dial gauges mounted on the lower rail flange, and bearing on a cased rod extending through the ballast into the subsoil clay. Rail stresses were measured by SR-4 strain gauges mounted on the center of the bottom of the rail flanges, and on each side of the web at the neutral axis. Readings were taken on one rail only. Both the measured deflections of the rail and the bottom of the ballast include a "seating error," but this is eliminated in the difference of the two readings which gives the deflection of the top of the subsoil. Under the E 66 loadings appreciable permanent displacement occurred of the ballast which also results in an error in the rail and ballast deflections but not in the subsoil deflections.

Fig. 6 shows the wheel loadings used. These were closely equivalent to E 66, E 40 and E 11 loadings.

Fig. 7 shows the locations of the deflection and rail stress measuring points for Section 1. Deflection points were spaced at 5 ft, and there were 3 rail stress measuring installations in each test section.

All readings were taken under static loading conditions. Before any readings were taken the E 66 load was run back and forth several times over all test sections.

(Text continued on page 935)

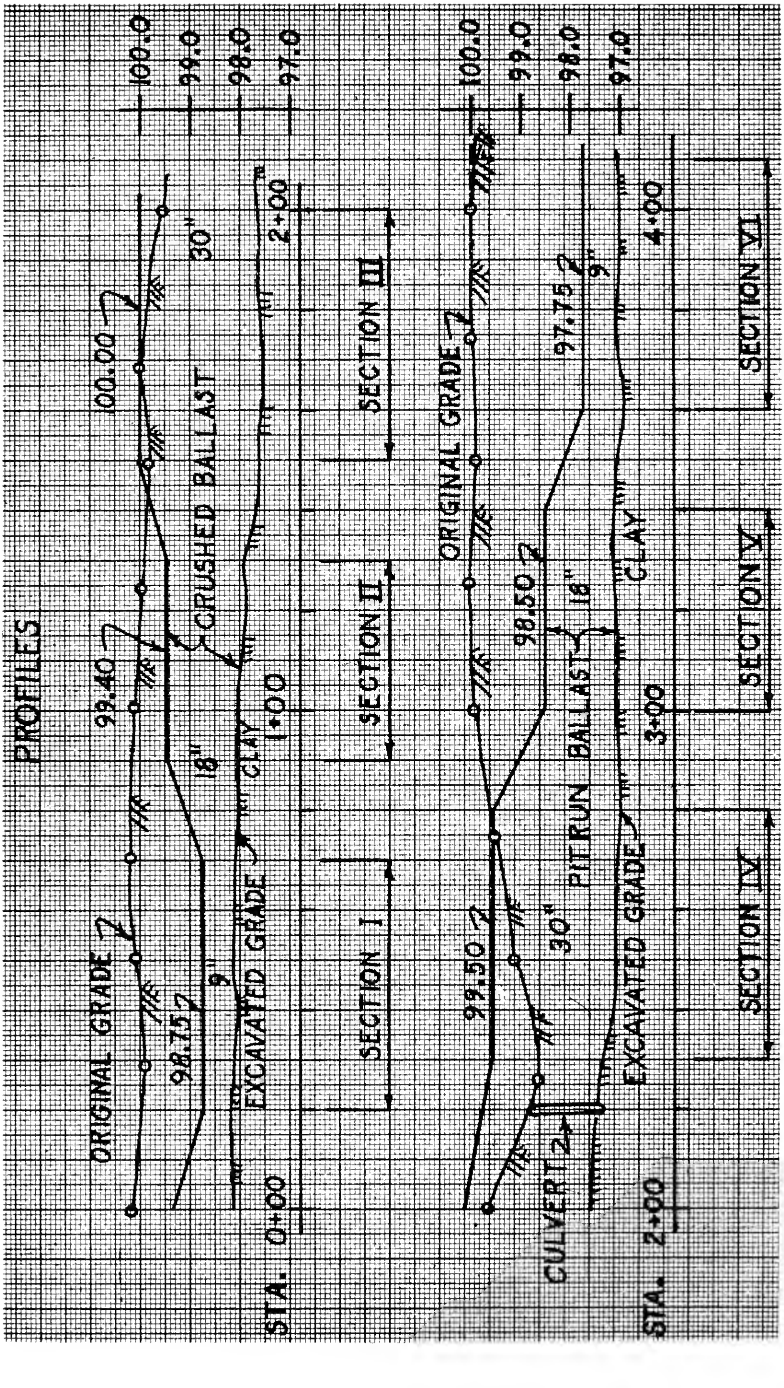

PROFILES
ORIGINAL GRADE
99.40
100.00
98.75
9"
18"
CRUSHED BALLAST
30"
EXCAVATED GRADE
CLAY
STA. 0+00
1+00
2+00
100.0
99.0
98.0
97.0
SECTION I
SECTION II
SECTION III
99.50
98.50
97.75
ORIGINAL GRADE
CULVERT
30"
PIT RUN BALLAST
18"
9"
EXCAVATED GRADE
CLAY
STA. 2+00
3+00
4+00
100.0
99.0
98.0
97.0
SECTION IV
SECTION V
SECTION VI

Fig. 2

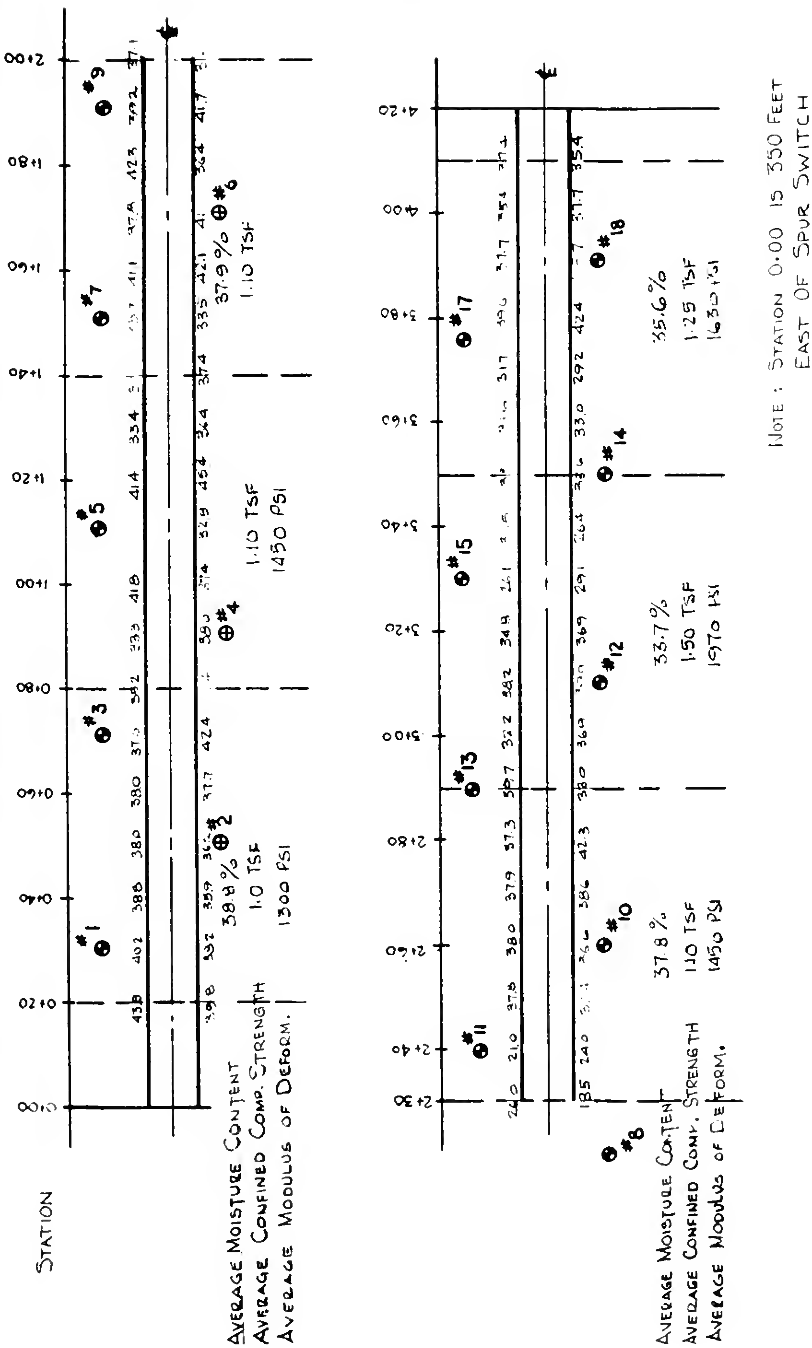

Station
Average Moisture Content
Average Confined Comp. Strength
Average Modulus of Deform.
1.0 TSF
1300 PSI
1.10 TSF
1450 PSI
37.9 %
1.10 TSF
37.8 %
1.10 TSF
1450 PSI
33.7 %
1.50 TSF
1970 PSI
35.6 %
1.25 TSF
1630 PSI
Note: Station 0.00 is 350 Feet East of Spur Switch

Fig. 3

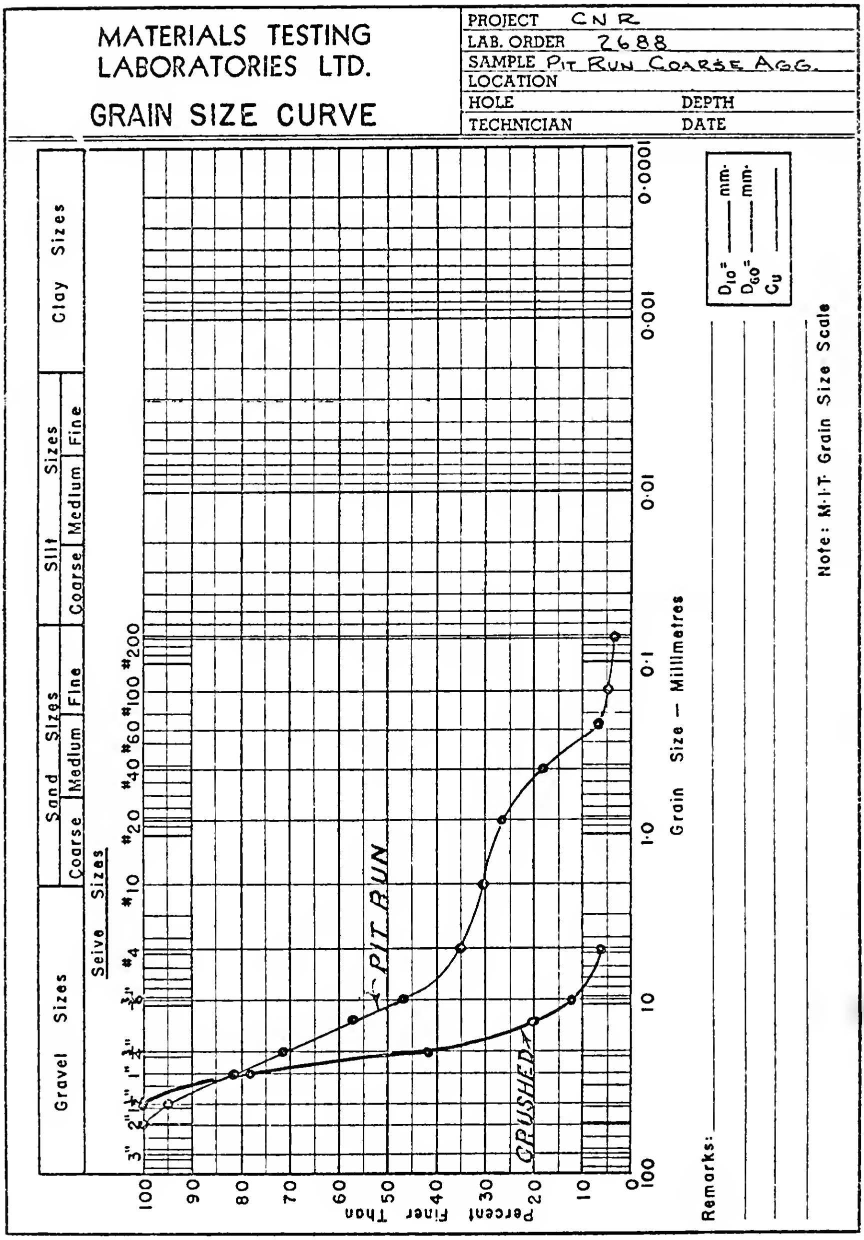

MATERIALS TESTING LABORATORIES LTD.
GRAIN SIZE CURVE
PROJECT CNR
LAB. ORDER 2688
SAMPLE PIT RUN COARSE AGG.
LOCATION
HOLE
DEPTH
TECHNICIAN
DATE
Gravel Sizes
Sand Sizes
Coarse
Medium
Fine
Silt Sizes
Coarse
Medium
Fine
Clay Sizes
Seive Sizes
3" 2" 1½" 1" ½" ⅜" #4 #10 #20 #40 #60 #100 #200
PIT RUN
CRUSHED
100 90 80 70 60 50 40 30 20 10 0
Percent Finer Than
100 10 1·0 0·1 0·01 0·001 0·0001
Grain Size — Millimetres
D_{10} = mm.
D_{60} = mm.
C_u
Remarks:
Note: M·I·T· Grain Size Scale

Fig. 4

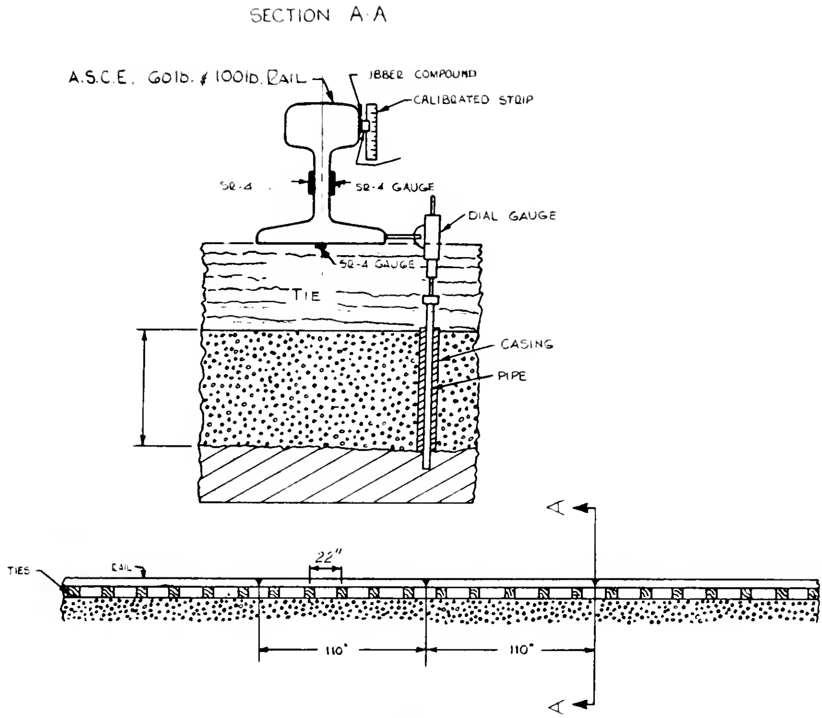

SECTION A-A
A.S.C.E. 60lb. & 100lb. RAIL
JBBER COMPOUND
CALIBRATED STRIP
SR-4
SR-4 GAUGE
DIAL GAUGE
SR-4 GAUGE
TIE
CASING
PIPE
TIES
RAIL
22"
110"
110"
A
A

Fig. 5

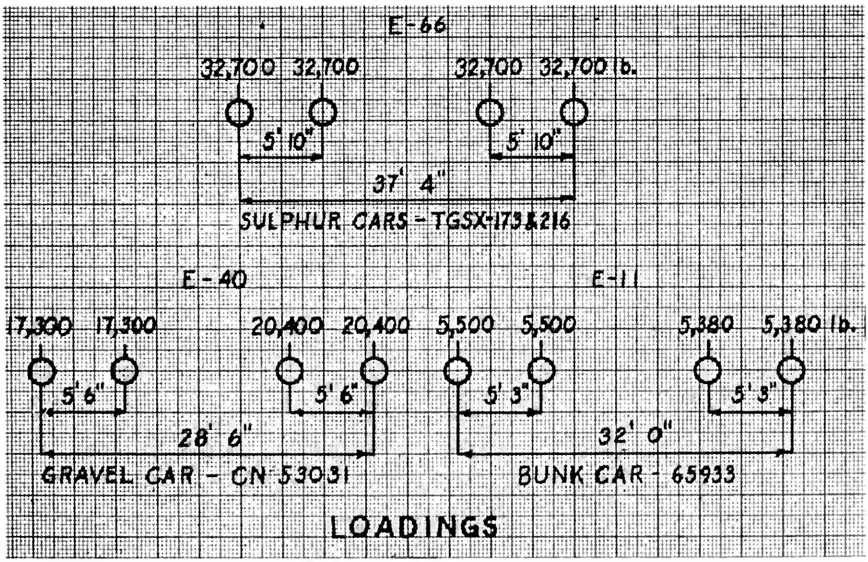

E-66
32,700 32,700
32,700 32,700 lb.
5' 10"
5' 10"
37' 4"
SULPHUR CARS - TGSX-173 & 216
E-40
E-11
17,300 17,300
20,400 20,400
5,500 5,500
5,380 5,380 lb.
5' 6"
5' 6"
5' 3"
5' 3"
28' 6"
32' 0"
GRAVEL CAR - CN 53031
BUNK CAR - 65933
LOADINGS

Fig. 6

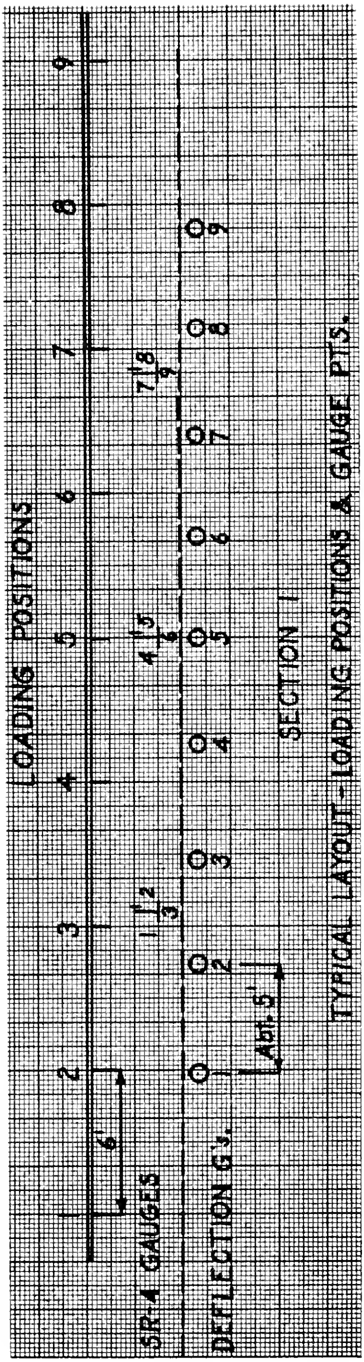

LOADING POSITIONS
1
2
3
4
5
6
7
8
9
SR-4 GAUGES
6'
DEFLECTION G's.
Abt. 5'
SECTION I
TYPICAL LAYOUT-LOADING POSITIONS & GAUGE PTS.

Fig. 7

Initial readings were then taken on all gauges. The first loading car was then moved onto the test section and spotted with its leading wheel over test position 1. A complete set of readings were then taken on the gauges in that test section. The front wheel of the car was then moved ahead 5 ft and spotted over position 2, and all readings were then repeated. This procedure was continued until the front wheel had occupied all test positions on the section. The car was then run off and all readings repeated. It was found that the cars could be positioned within a tolerance of about ± ¼ inch.

Sixty-pound rail was laid first on the test section, and after a complete set of tests were run it was replaced by 100-lb rail. The program has been completed for the ballast in a loose density state. The second stage involved densifying the ballast, and repeating all tests. This has not as yet been undertaken.

The portion of the test program completed to date has accumulated many hundreds of individual readings, and these can be analyzed in a variety of ways. Much of the data for any one of the six test sections for a particular loading can be presented in plots such as on Fig. 8. These are of the raw data. Theoretical plots of track deflection are also shown. In these plots the wheel loads are taken as being in a fixed position and the readings from each recording station are plotted in their proper horizontal location with respect to the wheels. The accuracy of the instrumentation was about ± 300 psi for stresses and 0.01 inches for deflections. However, it is obvious from both the stress and deflection data that the actual tolerance considerably exceeds these figures. The greatest uncertainty arises from variations in density of the ballast. This was inevitable with the material being placed in a loose condition without tamping. Tests on densified ballast would be expected to show less tolerance. A second important source of error in the stress measurements is in the positioning of the wheels, both laterally and parallel to the rail.

The stress and deflection distributions away from wheel points require statistical analysis of the data to make them meaningful. Nevertheless, several conclusions pertinent to the upgrading program are clearly evident from the raw data.

Fig. 9 shows a tabulation of the maximum rail stresses both in the web and flange of the rails for the various test conditions for the E 66 and E 40 loadings. The following conclusions appear to be valid from the data, but applicable to the particular conditions of ballast and subsoil at the test site:

1. The difference in performance between the crushed and pit-run ballast at low densities is not significant, although the performance of the crushed rock appeared to be slightly better.
2. The uniformity of the ballast with respect to density appears to be of greater importance with respect to rail stresses than the thickness of the ballast.
3. The web stresses vary widely and appear to be more sensitive to variations in ballast quality and wheel positioning than the flange stresses.
4. The stresses in 60-lb rail under E 40 loading are not excessive, and this is also true for the 100-lb rail under E 66 loading. However, the stresses in the 60-lb rail under E 66 loading were as high as 33,500 psi compression in the web and 35,700 psi tension in the flange. These stresses are excessive for static loadings.

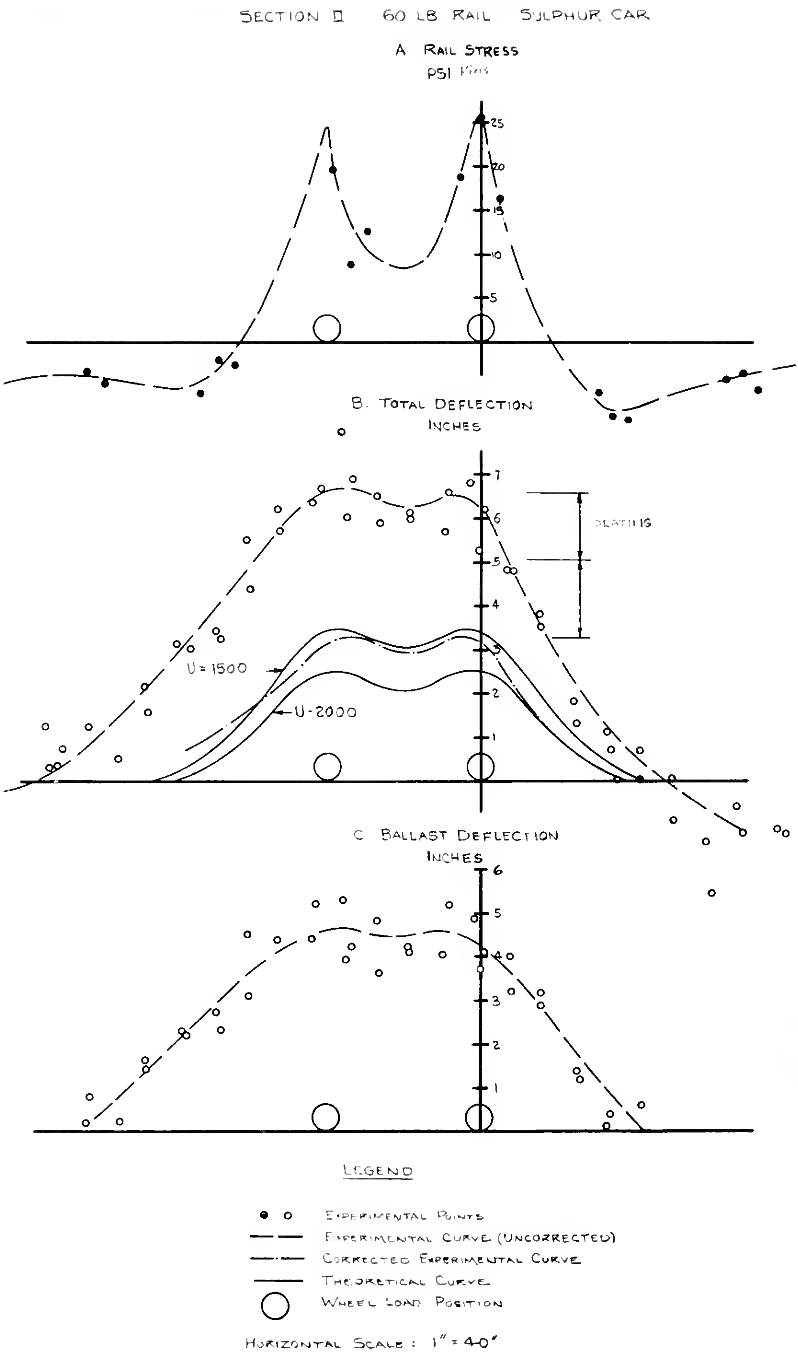
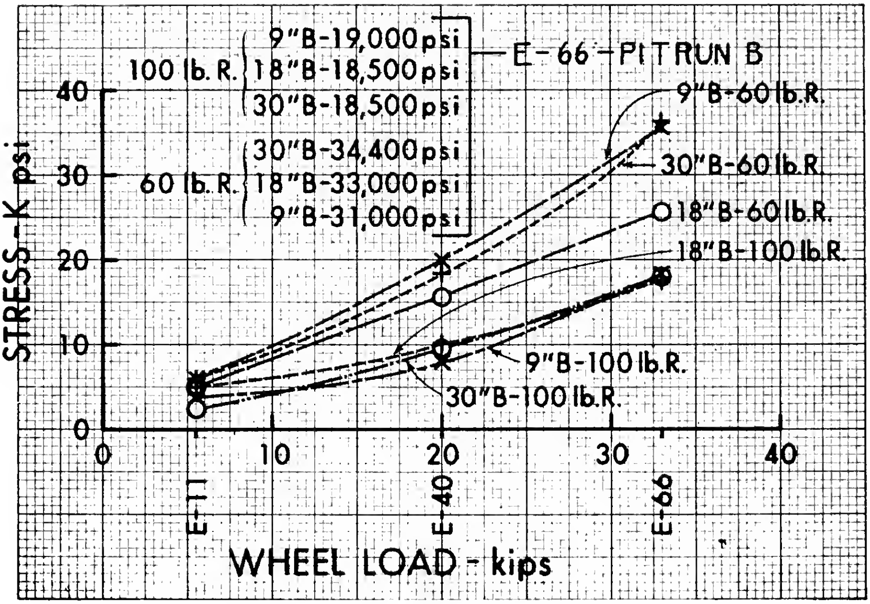

SECTION II 60 LB RAIL SULPHUR CAR
A RAIL STRESS
PSI
25
20
15
10
5
B. TOTAL DEFLECTION
INCHES
7
6
5
4
3
2
1
U = 1500
U-2000
C BALLAST DEFLECTION
INCHES
6
5
4
3
2
1
LEGEND
EXPERIMENTAL POINTS
EXPERIMENTAL CURVE (UNCORRECTED)
CORRECTED EXPERIMENTAL CURVE
THEORETICAL CURVE
WHEEL LOAD POSITION
HORIZONTAL SCALE : 1" = 40'

Fig. 8

MAX. RAIL STRESSES — Kips per sq. in. — + = Tension, − = Comp.

BALLAST THICKNESS	CRUSHED BALLAST												PIT RUN BALLAST					
	60 lb. RAIL						100 lb. RAIL						60 lb. R.			100 lb. R.		
	E-66			E-40			E-66			E-40			E-66			E-66		
	Web +	Web −	Flange +	Web +	Web −	Flange +	Web +	Web −	Flange +	Web +	Web −	Flange +	Web +	Web −	Flange +	Web +	Web −	Flange +
9 in.	8.6	33.5	35.7	1.7	12.2	20.0	−12.2	2.0	14.7	−7.4	2.1	6.5	−6.1	+4.0	25.4	2.1	16.2	19.1
18	20.3	27.0	25.8	2.1	6.2	12.4	1.0	15.8	14.6	−0.3	5.5	10.1	−13.6	6.8	29.7	−5.5	0.8	18.0
30	−7.0	4.8	29.4	6.0	14.5	15.7	2.6	14.7	17.9	1.6	8.0	9.8	6.5	17.9	34.4	−3.0	6.6	16.1

Fig. 9



MAX. STRESS IN BOTTOM OF RAIL FLANGE-CRUSHED ROCK BALLAST

Fig. 10

5. Fig. 10 shows plots of maximum flange stress vs. loading. An obvious conclusion from these plots is that the 100-lb rail is much more effective in "ironing out" irregularities in the ballast than is the 60-lb rail.
6. Even without the second stage of the test program in which the ballast was to be densified, the original question as to the possibility of compensating for 60-lb rail by increasing the stability of the ballast and/or subsoil can be answered. It cannot be achieved, mainly for the reason that the web stresses in the 60-lb rail would still be exorbitantly high. In fact the most substantial benefit that could be most quickly secured would be to replace the 60-lb rail with 100-lb rail.
7. Fig. 11 shows plots of deflection of subgrade vs. wheel load.

The deflections in the subgrade did not exceed 0.15 inches, and this value was only some 20 percent of the maximum rail deflections measured. The subgrade therefore was relatively stiff as compared to the loose ballast materials. The plots on Fig. 11 indicate that the weight of rail has a comparatively small influence on the deflections in the subgrade. Moreover, while the subgrade deflection appeared to be sensitive to the thickness of the ballast with the E 11 loading, it was only slightly affected by the two heavier loadings. The predominant factor influencing

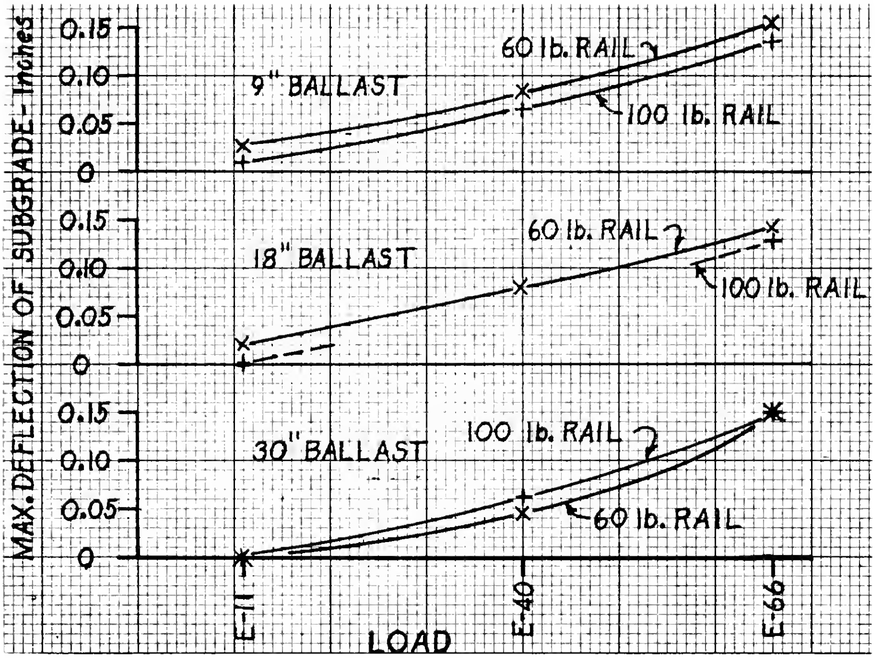


Fig. 11

the subgrade deflection appears to be the wheel load. The subgrade deflections were about doubled by the E 66 loading as compared to the E 40 loading, irrespective of the ballast thickness. On theoretical grounds this relationship is unlikely to be greatly altered by increased stiffness of the ballast.

This does not mean that no benefits are to be gained by increasing the weight of rail and thickness of ballast. However it does point up a particular problem with the subgrade soils in roadbed upgrading procedures. If the subgrade soils are of types susceptible to strength deterioration by straining, then a new cycle of subgrade troubles can be initiated by the increased wheel loads, which will be largely independent of upgrading of the other track structure elements. Unfortunately, soils with these characteristics are of wide occurrence in Western Canada. In many locations upgrading of the subsoil conditions is therefore just as necessary as the improvement of other elements in the track structure.

As a generality, perhaps the most significant aspect of this particular case history lies in the record of performance under wide extremes of conditions. It is a case of very low standard of construction in which the loadings were greatly increased almost overnight. The record of performance perhaps only reiterates what has long been known, but it does point up the necessity of considering all elements of the track structure in assessing the effect of increased intensity of traffic. It also is of more than passing interest to note that modern techniques of soil mechanics and the relatively more sophisticated instrumentation now available can provide useful assistance in predicting track structure performance.

This study was undertaken under the authority of A. V. Johnston, chief engineer of the Canadian National Railways, E. S. English, regional engineer of the Mountain Region, and F. L. Peckover, engineer of soils and foundations for the CNR. The program was conducted by R. M. Hardy & Associates Limited, of Edmonton, acting as consultants to the CNR. The field tests were conducted under the direction of John Hayes.

(Applause)

Chairman Webb: Dr. Hardy, on behalf of Committee 1 and the Association, I wish to thank you for a very interesting presentation.

Mr. Vice President, this concludes the report of Committee 1.

Vice President Williamson: Thank you, Mr. Webb, for that report, and the efforts of you and your committee this past year.

Dean Hardy, we especially thank you for being with us today, and for that splendid discussion on Stress Distribution in Track Structure. You have certainly done a lot of research on this subject, and have given us a great deal of information. We thank you.

Mr. Webb, your committee is now excused with the thanks of the Association. (Applause)

Discussion on Track

(For report, see Bulletin 612, pages 555–571)

Vice President Williamson: Gentlemen, the next to the last committee to present its report before this session is Committee 5—Track. The chairman of this committee is C. E. Peterson, assistant engineer, Atchison, Topeka & Santa Fe Railway.

Mr. Peterson, you may proceed as soon as your committee is ready.

Chairman C. E. Peterson: The report of the Track Committee, covering our nine assignments, will be found in Bulletin 612, February 1968. The work on some of our assignments has resulted in recommendations affecting the Manual; the work on others has resulted in reports published as information. Each subcommittee is continuing to progress old assignments and is also working on new assignments.

The Board Committee on Assignments has approved the complete reorganization and rewording of Committee 5 Assignments. In the new list the subcommittee subjects are specifically defined in order to equalize the membership of subcommittees under each assignment. This will enable the committee to work more effectively.

Today I will call for reports only from the subcommittee chairmen of Assignments 3 and 10.

Before doing so, however, I will introduce the other subcommittee chairmen of the committee. As I call his name, I ask that each stand and be recognized, remaining standing until all have been introduced.

V. M. Schwing, chief engineer, Union Railroad, chairman of Subcommittee A.

C. D. Davis, engineer track, Long Island Rail Road, chairman of Subcommittee 1.

T. L. Biggar, general supervisor of track, Chesapeake & Ohio–Baltimore & Ohio, chairman of Subcommittee 2.

L. A. Pelton, division engineer, Penn Central, chairman of Subcommittee 5.

E. C. Honath, district engineer, Santa Fe, chairman of Subcommittee 6.

R. P. Roden, retired assistant engineer, Union Pacific, chairman of Subcommittee 7.

L. W. Green, engineer of track, Penn Central, chairman of Subcommittee 9.

C. L. Gatton, assistant to chief engineer, Louisville & Nashville, chairman of Subcommittee 12.

Gentlemen, I thank you for a job well done. Please be seated.

Assignment 3—Standardization of Trackwork Plans

Chairman Peterson: I shall now call on C. J. McConaughy, track designer, Southern Pacific Company, to present the report on Assignment 3.

C. J. McConaughy: Mr. President and gentlemen:

Bulletin 612 of February 1968 covers Subcommittee 3's report, which is submitted as information.

Bulletin 610 of December 1967 covers Manual recommendations submitted to the AREA Board of Direction for approval. Article 7—Malleable and Ductile Iron Castings, and Article 14—Bolts and Nuts, on pages 358, 359 and 360 of this Bulletin, have been approved for inclusion in the Specifications of the Portfolio of Trackwork Plans.

Our investigation on improvements of the design of manganese insert frogs for the purpose of extending their service life, has developed that the wide-flange wheels which are being reworked to narrow flange without remounting on the axle, are affecting both the frogs and the guard rails. The change in the wheel flange contour, approved by the Mechanical Division, Wheels and Axle Committee, is mentioned in Bulletin 605 of February 1967, page 361, and Bulletin 607 of June–July 1967, page 629.

It appears at this time that the guard rail gage should be widened or, possibly, the gage of the track should be changed. Lengthening the taper approach on the guard rail should reduce the impact in guiding the wheels through the frog. It may also prevent the back of the wheels from striking the guard side of the frog flangeway.

In the investigation of guard rail design, consideration should be given to the canted plate for the guard rail the same as provided on the manganese guard rail. The present available canted guard rail plate, 7½ inches wide, is inadequate where the larger tie plates are used.

The revised plan for the AREA spring rail frog as outlined in Bulletin 612 of February 1968, has been approved by your committee and will be submitted for adoption this year.

The assignment on explosion hardening of frogs should include comparison with the press-and-hammer hardening of manganese castings that is being furnished to various railroads. This should apply to turnout frogs and track crossings.

In reviewing AREA Plan No. 791–59, Practical Gages and Flangeways, consideration should be given to the new wheel contours and longer cars.

The new committee organization intended to reduce the number of members on each subcommittee may impair the opportunity for thorough discussions. To arrive at an engineering design change, we should consider the railroads' views to determine if it is applicable. When the subcommittee assignments are issued, each member should investigate how they apply to their respective railroads, and whether any material adopted under them will be used. This will produce more efficient discussions at the meetings and expedite handling of letter ballots.

Mr. Vice President, that concludes the report on Subcommittee 3.

Assignment 10—Modern Methods of Heat Treating Carbon Steel Trackwork and Repairing Such Trackwork by Welding

Chairman Peterson: Assignment 10 will now be reported on by S. H. Poore, who retired recently as office engineer on the C&O–B&O.

S. H. Poore: Mr. Chairman and gentlemen: The report is on page 564, Bulletin 612.

This project started in 1954 on the Milwaukee Road at Mannheim, Ill. Several frog and switch producers participated, together with several welding companies. There has been a large volume of material on the project published by the Track Committee from 1954 down to about 1964. They are all listed in the committee's report.

However, the significant part of this report is the table appearing on page 567. The track panels, a sketch of which is shown as Fig. 1, were put in track and after carrying 91,000,000 gross tons of traffic they were ready for grinding and building up by welding. Several welding techniques were used. After welding, hardness readings and wear readings were taken.

After the welded panels had carried 208,000,000 gross tons of traffic, more wear readings were taken. The table on page 567 shows that the trackwork after welding displayed virtually a uniformally increased resistance to wear and batter over the original metal.

Several comparisons were made; for example, there were samples of carbon steel rail, non-heat-treated rail, flame-hardened rail, fully heat-treated rail and a piece of chrome–vanadium rail. Virtually all of the samples showed an increase in wear resistance after welding.

The committee's report sets forth some tentative conclusions which we believe will point the way to better trackwork materials and welding procedures in the future.

Chairman Peterson: The committee wishes to express its appreciation to G. M. Magee, assistant vice president—research, AAR and K. W. Schoeneberg, research engineer—track, AAR, for their assistance to the committee.

Mr. Vice President, this concludes the presentation of the report of Committee 5.

Vice President Williamson: Thank you, Mr. Peterson, for that report and the excellent work your committee has accomplished for this Association. Your efforts are greatly appreciated. You and the committee are now excused.

Discussion on Engineering and Valuation Records

(For report, see Bulletin 610, pages 215–227)

Vice President Williamson: Gentlemen, the final committee report at this session of the 1968 convention is Committee 11—Engineering and Valuation Records. The chairman of this important committee is H. R. Williams, valuation engineer, Union Pacific Railroad, Omaha, Neb.

Mr. Williams, you may proceed as soon as you are ready.

Chairman H. R. Williams: Committee 11 is pleased to have the opportunity of appearing before this—the last session of the 1968 AREA convention. Our presentation will be brief. It will include a report on one of our assignments. Then we will show a new colored movie which I think you will enjoy.

In 1967 Committee 11 had seven major assignments under study. Reports on five of these are included in Bulletin 610 of December 1967.

Before proceeding I would like to introduce our officers and subcommittee chairmen who will not be giving oral reports.

Committee Secretary: Richard S. Shaw, valuation engineer, Penn Central.

Assignment 1—Revision of Manual: Chairman, John L. Manthey, auditor of property and material accounting, Elgin, Joliet & Eastern.

Assignment 4—Special Studies: Chairman, Milton Wolf, valuation engineer, Northern Pacific.

Assignment 5—Application of Data Processing: Co-chairman, Larry F. Grabowski, auditor of capital expenditures, C&O–B&O; Co-chairman, Harold C. Boley, valuation engineer, Santa Fe.

Assignment 6—Valuation and Depreciation: Chairman, Chester Dolan, engineer–capital expenditures, Missouri Pacific.

Assignment 7—Revision and Interpretation of ICC Accounting Classifications: Chairman, Robert D. Igou, manager of capital expenditures, Rock Island.

Assignment 3—Office and Drafting Practices

Chairman Williams: Next, reporting on Committee Assignment 3 will be Subcommittee Chairman James H. Robinson, engineer capital expenditures, Burlington Lines. His subject is, "Microfilming of Engineering Records and Reports." Mr. Robinson.

Microfilming of Engineering Records and Reports

J. H. Robinson: Mr. Vice President, the report of Subcommittee 3 appears on page 221 of Bulletin 610.

Our study on microfilming of engineering records and reports has extended over several years and reports have appeared in Bulletins in 1963, 1965, 1966 and 1967. I would like, at this time, to take a few minutes to boil down the meat of these reports into answers to the questions we hear mostly these days: Why and how much?

Microfilming is not a modern invention; it dates back to 1841 when a handbill 14 inches long was reproduced on a negative only ⅛ inch in length. Like railroading, however, there have been a great many improvements since then.

There are several reasons for microfilming, but two of them are of paramount importance, safety or security and conservation of storage space. A large majority of our records would cost a fortune to replace should fire, flood, tornado or other disaster destroy them. Many could never be replaced. For security reasons, therefore, these records should be microfilmed and the films stored where they are as safe from disaster as it is possible for them to be.

Storage space is rapidly becoming a major problem and, with building costs what they are today, one which has a price tag on it. Many files which must be referred to from time to time occupy space that could be utilized to better advantage. By having a duplicate or working film made at the same time the security film is made, and having it cut and placed in small acetate jackets, files taking up several thousand square feet of floor space can be condensed into less than a hundred square feet.

Today, more than ever before, we are all cost conscious; but in considering the cost of microfilming, we should also consider the cost of replacing the records should disaster strike. We then have two questions to weigh against each other: "Can we afford to do it?" and "Can we afford not to do it?"

The major problem is the backlog of records and reports which have accumulated. For many roads the volume is such that it might be best to have this done commercially. Even then it might take a year or more to complete the job. Whether done by company forces or commercially, taking care of the backlog is going to be an expensive job.

Commercial plants generally require that material to be microfilmed be free from pins, clips, staples or other binding agents and be ready for normal filming operations. While this is being done, the file can be stripped of duplicate letters, forms, etc., as well as papers that it is very apparent do not have to be retained. For other papers it is cheaper to microfilm them than to have experienced and trained personnel spend time weeding them out.

With filming done commercially, using 16-mm black-and-white film for ordinary documents, and color film where color is involved, and having both a security film and a working film made at the same time, the cost will average about 10 cents per document. About two-thirds of this cost is for your own forces preparing the files for microfilming. To utilize the working films, at least one reader–printer will be required and one or more ordinary viewers. The reader–printer enables you to either read the required information direct from the microfilm or to make a blowup copy to take with you for further study or use. Reader–printers will cost about $1,500 and ordinary viewers about $500. Cabinets for the jackets and storage of roll films will cost about the same as the ordinary card file.

After the backlog has been taken care of, the microfilming of current items does not present a serious problem. The cost will depend upon how elaborate a setup you might desire. For approximately $12,000 you can obtain a camera, processor, inspection equipment, reader–printer and hand mounter for inserting film strips into jackets.

Retrieval systems can be installed whereby, through a coding system, the proper file drawer is made readily available for your securing and refiling the desired microfilm jacket. In fact, it is possible to have a system installed whereby, through closed circuit television, you can dial a file control a thousand miles away; the desired jacket is automatically retrieved and inserted in a televiser for your viewing and then automatically refiled, all in a matter of seconds. This, I might add, is rather expensive at present.

Undoubtedly most of those present have been contacted regarding benefits to be obtained from computers and data processing. Total informational systems are rapidly becoming a must in this rapidly expanding electronics age. Microfilming can also be utilized into such an informational system through key punch cards with aperature for the negative.

CHAIRMAN WILLIAMS: We have on Committee 11 a key officer who rates high in many fields—engineering, photography, gourmet cooking, playwriting. It is my privilege to introduce our committee vice chairman, J. Bert Byars, who will present our special feature: Motion Picture on Construction of Denver & Rio Grande Line Change, Including Negotiations Between Railroad and Governmental Agencies.

Mr. Byars.

Motion Picture—Construction of D&RGW Line Change, Including Negotiations Between Railroad and Governmental Agencies

By J. B. BYARS

Assistant to Chief Engineer, Denver & Rio Grande Western Railroad

J. BERT BYARS: Thank you, Mr. Williams. Mr. Vice President, Members of AREA and guests: When we were approached about a special feature for this convention, they said they wanted something of interest, also something colorful. We feel our movie is very colorful; perhaps we from Colorado, being just a little bit prejudiced, feel that it might show some of the most colorful parts of the United States.

Committee 11 is interested in presenting this film because we think many of you have had experiences with the different governmental agencies in getting work done that involves their participation in cost. I would like to say here that we have had splendid cooperation with the State Highway Department of Colorado on this project and on many other projects which we have under construction.

The Bureau of Public Roads is somewhat different. They have strict PPM30–3 which regulates the division of costs on projects of a joint nature. We took the stand, in the beginning, that we were happy with our location on the north side of the river (the sunny side) and not up against a cliff where slides would be prevalent. If we were to ask our Board of Directors for any money to construct a line change, we would much prefer to go a little farther west and put in one where we could take out some curvature and shorten the track. This is what caused considerable argument in the negotiations.

As many of you know, under regulation PPM30–3 we are supposed to allow for any depreciation on an old structure which is replaced by the government. This project involved seven miles of new main line, a new yard, stockyard, communications system and signal system; we had an old stockyard. We finally told them in negotiation that if they didn't want to pay for the new stockyard, we would move the old one by taking out the old nails, carefully removing all boards so they wouldn't split, and relocate it across the river. They decided they would pay for the new stockyard.

Incidentally, the Highway Department purchased all of the right-of-way. Some of it was actually traded for the present right-of-way, and the difference in acreage was appraised and settled on that basis. The grading, fences and so forth were constructed by contract for the State Highway Department at its expense.

The track construction, the yard construction, the stockyard, the piggyback ramps, and the communications and signal systems were constructed by the railroad company and paid for by the State Highway Department. Our standard 136-lb rail was laid in the main line and the railroad company paid for the increase in rail weight of 136-lb over that in the old line of 133-lb and 119-lb. The estimate of our cost for the work we performed was about $1,750,000, of which the railroad company will pay about $85,000.

Now if we may have the film. (The film was shown, with commentary by Mr. Byars.)

(Applause)

Chairman Williams: Mr. Vice President, this concludes the report of Committee 11. It also marks the end of my term as chairman of the committee. The job has been stimulating and rewarding and I wish to thank the subcommittee chairmen and members for their assistance and active participation. I am also indebted to the officers of the Association and Executive Secretary Earl Hodgkins and his staff for their complete cooperation. Thank you.

I will now introduce the officers of the committee for the ensuing term: The new chairman of Committee 11 is J. Bert Byars, assistant to chief engineer, Denver & Rio Grande Western Railroad. The new vice chairman is Chester R. Dolan, engineer capital expenditures of the Missouri Pacific Railroad. Our past, present and future secretary is Richard S. Shaw, Jr., valuation engineer, Penn Central. (Applause)

Vice President Williamson: Thank you, Mr. Williams and the members of Committee 11 for your efforts during the past year. Yours is a very specialized area and we look to you for guidance and information.

Mr. Byars, we appreciate your efforts in preparing that excellent motion picture and your narration of it. It was most interesting and informative.

Mr. Williams, we are grateful to you for your outstanding leadership which you have given to Committee 11 for the past three years.

As you are relieved of your responsibilities as chairman, we are pleased to welcome Mr. Byars as your successor and Mr. Dolan as the new vice chairman of the committee. We are satisfied from their past performances that under their direction the good work of this Committee 11 will continue.

Mr. Byars, as a symbol of your new authority and to assist you in conducting the meetings of your committee, I would like to present you with this chairman's gavel. The inscription reads:

"J. Bert Byars, Chairman AREA Committee 11, 1968—1970."

(The gavel was presented to Mr. Byars.) (Applause)

Vice President Williamson: Mr. Williams, your committee is now excused with the thanks of the Association.

I will now turn the chair back to our good president, Mr. Hutcheson.

(President Hutcheson resumed the chair.)

President Hutcheson: Ladies and Gentlemen, we have now completed all of the committee reports to come before this convention. I do hope that all of you will stay for the business session which will convene immediately.

You will be interested to know that R. E. Dove of Railway Track and Structures, who looks after such matters, has reported to me that the total registration for this Convention is 3,153. This makes the 1968 Convention registration the largest in the Association's history and exceeds the total registration of the 1965 convention, which heretofore held the record, by 696. Your officers and directors are indeed gratified by the support which the Association has received from its members.

(The meeting adjourned at 12 o'clock)

Closing Business Session

PRESIDENT HUTCHESON: I now convene the Closing Business Session of the 1968 Annual Convention, which will include the installation of officers for the ensuing year.

First I want to take the opportunity to thank all who have contributed to the work of our Association during the past year, and to the success of this convention. Our Association has indeed had another productive year. This is true because so many of you gave generously of your time and effort, which I assure you is appreciated, not only by your officers and directors, but also by the industry which we serve.

There are so many to whom I am personally indebted that I cannot name them all here, but I do want to express my personal appreciation for the splendid cooperation of our officers and directors, our committee chairmen and members, to the office of the executive secretary and to all others who have contributed in any way to the success of the 1967–1968 Association year.

It is necessary and desirable that I emphasize the assistance which I have received from the office of the executive secretary. Mr. Hodgkins and his staff performed splendidly as they conducted the Association's affairs during the past year. Their careful attention to every detail in the planning and execution of the Association's programs and publications, many times under extremely difficult conditions and circumstances, has been invaluable to the Association, to the Board of Direction and to me. The terrific work load placed on this office, small in number of personnel, by the formation of the Bridge Safety Committee at the time that office was going into its busiest season, and the splendid results the staff turned out during that period of double work load, are matters that you should all know about and appreciate as I do.

The General Convention Arrangements Committee under the able direction of Bruce Miller and Jack Spangler did an outstanding job this year with their usual multitude of duties and assignments in executing the arrangements made by the staff for this Convention.

These well planned Conventions do not just happen. Other than our past presidents, there are few in position to know the multitude of details handled by this committee during our Convention and how easy it is for things to go awry, if it were not for their abilities and dedication.

An important part of our Convention has been the ladies' activities. These have been well attended and I hope much enjoyed by the ladies. A total of 251 ladies have registered at the convention.

I join Mrs. Hutcheson in thanking all of those ladies who with Mrs. Wilson, Mrs. Williamson and Mrs. Hodgkins, gave so generously of their time in assisting in the social functions of our Convention for the ladies. Our sincere thanks.

Is there any other business to come before this meeting?

Past President J. M. Trissal: Mr. President, may I have the floor?

Ladies and Gentlemen, President Hutcheson: One of the nice things about being a past president is that you have no particular responsibilities during the conduct of the meeting. Tom, on the other hand, has really had a job, with the biggest Convention ever. If the difficulties were proportionate to the attendance, Tom has had the toughest job any AREA president ever had. He also had an opportunity to put into effect some new practices which I am sure we all agree added a great deal to the Convention. Our new way of handling Manual material gave us additional time for some excellent special features.

Now it is my pleasure to present to you a little additional hardware. But I want you all to take a look at the condition of the package. It just arrived by U.S. Mail. (Laughter)

Tom, I would like to read what is inscribed on this plaque which I am about to present to you. Incidentally, I think you will learn something which I am just now learning, and that is what Tom's middle name is. The inscription says:

THE AMERICAN RAILWAY ENGINEERING ASSOCIATION RECORDS ITS GRATEFUL APPRECIATION TO THOMAS BARKSDALE HUTCHESON FOR HIS ABLE ADMINISTRATION OF THE AFFAIRS OF THE ASSOCIATION DURING HIS TERM AS PRESIDENT, 1967–1968.

Congratulations, Tom, and while you are not quite through your job, I do want to welcome you to the society of has-beens.

(A plaque was presented to President Hutcheson.)

(Applause)

President Hutcheson: Thank you, Jack. I greatly appreciate this lovely plaque. It shall occupy a place of prominence in my home. These are humbling experiences and I am deeply appreciative to the Association for the confidence it has displayed in me. This is one of the nicest things that has ever happened to me and this plaque will be a constant reminder of a most pleasant year.

The close of our Annual Convention each year brings with it not only a feeling of satisfaction, but some regrets, because it brings to an end the services of several of our directors. I want to thank each member of the board for his counsel, advice and support and especially those members who, having completed their term of office, are retiring from the board.

The closing of this meeting completes the services on the board of Past President A. V. Johnston, chief engineer, Canadian National Railways. The constitution provides that past presidents will remain on the board for two years after completion of their term as president. We are deeply indebted to Mr. Johnston for his long and valuable service to our Association, both in an official and unofficial capacity. And although he will be off the board, I am sure he will still be called upon for counsel and advice as important matters require. And I am sure he will continue to render the outstanding service to the Association that he has for many years.

Other members of the Board of Direction completing their term of office are these directors:

D. H. Shoemaker, chief engineer, Northern Pacific Railway.

M. S. Reid, assistant chief engineer—maintenance, Chicago & North Western Railway.

J. A. Rust, senior assistant chief engineer, Southern Railway System.

These men have served our Association well in their official capacity on the board and I want to express our deep appreciation to each of them. Will Messrs. Shoemaker, Reid, Rust and Johnston stand and permit us to give them a hand? [Applause]

I regretfully announce the resignation from the Board of Direction of George V. Guerin, chief engineer, Great Northern Railway, who had an additional year to serve to complete his term. Mr. Guerin retired from Great Northern on February 29—it isn't everybody who has the opportunity to retire on that day—and felt it advisable to retire from the Board at the same time. His wise counsel and diligent service will be greatly missed.

It is now my privilege and pleasure to present the new directors and officers you have elected for the ensuing year. As I read your names, please come to the speaker's table and take a place on my right.

For the East District, J. F. Piper, chief engineer—maintenance, Penn Central Company, Philadelphia, Pa. [Applause]

C. T. Popma, assistant vice president—engineering, Penn Central Company, New York. [Applause]

For the South District, S. A. Cooper, chief engineer, Gulf, Mobile & Ohio Railroad, Mobile, Ala. [Applause]

For the West District, D. V. Sartore, chief engineer, Burlington Lines, Chicago. [Applause]

Acting under the provisions of the AREA Constitution, your Board of Direction has appointed Walter R. Bjorklund, director of industrial engineering, Northern Pacific Railway, St. Paul, Minn., as a director to fill the unexpired term of one year left by Mr. Guerin's resignation. Mr. Bjorklund, would you please come to the speaker's table and take your place beside the other new directors? [Applause]

Gentlemen, I welcome you as directors of the American Railway Engineering Association. It is an office of high honor and responsibility which you are assuming. I hope you will enjoy your service on the Board of Direction and that you will bring much value to its deliberations. [Applause]

Gentlemen, you may be seated.

Our new senior vice president is Harry M. Williamson, chief engineer—system, Southern Pacific Company, who under the provisions of the constitution automatically advances to this position from that of junior vice president.

Mr. Williamson, will you please come to the platform? [Applause]

Mr. Williamson, it is with much satisfaction that I see you advanced to this position of greater responsibility in the Association. Knowing of the past dedicated, able service which you have given to the Board, I know you will discharge this greater responsibility with much distinction. [Applause]

Your newly elected junior vice president is James B. Clark, chief engineer, Louisville & Nashville Railroad, who has just completed his three-year term as a director this year.

Mr. Clark, would you please come to the platform and take your place? [Applause]

Mr. Clark, I congratulate you upon your election as a junior vice president and for your continued service on the Board of Direction. You and Mr. Williamson will make a splendid team of vice presidents to serve this Association. [Applause]

Now your new president, Hal E. Wilson, assistant chief engineer system, Atchison, Topeka & Santa Fe Railway: To accord Mr. Wilson proper recognition, I have requested Past Presidents Beeder and and Trissal to escort him to the platform at this time.

[Mr. Wilson was escorted to the platform.]

[Applause]

President Hutcheson (continuing): Mr. Wilson, I want to congratulate you upon your election to the highest position of honor in this Association and I now proclaim you president, and your lovely wife as the official first lady of this Association.

I share the confidence of the membership which has been placed in you, and it is with extreme pleasure and satisfaction that I turn the responsibility of president over to you, knowing that it will be discharged in a most satisfactory manner.

In doing so, I want to present you with this solid gold pin which will bear these words engraved on the back:

"H. E. WILSON, PRESIDENT, 1968–1969."

It is the official emblem of the AREA and I am sure you will wear it with pride and pleasure.

[The pin was presented to Mr. Wilson.]

[Applause]

President Hutcheson (continuing): Before I relinquish my responsibilities, I have one more thing to say.

As some of you may have heard, certain nefarious activities have taken place at this Convention The Association and a number of individuals have been relieved of certain of their possessions. The box in which we had the engraved emblem we were to present to Mr. Wilson was made off with by some one, thieves, I guess, the other night, and we will have to have the one I just presented engraved, so if you will return it for that purpose, we will have it done.

I now turn this podium over to Mr. Wilson. [Applause]

[Mr. Wilson assumed the chair as president.]

President Wilson: Thank you, Mr. Hutcheson. Thank you, members and guests of the Association. I am grateful to you for this great honor you have bestowed upon me. In looking back at the long list of illustrious predecessors in this office, I have become well aware of the challenge which confronts me.

I am not going to make a long speech, but I wish to say one thing; I was surprised and disturbed at one remark made by Mr. Lang Tuesday, when he indicated that some members of the Association felt that the AREA Board of Direction was pretty much hidebound and was reluctant to accept any suggestions on any matters.

I do not think this is the case. The Board has always been willing to accept suggestions and recommendations and will continue to do so. Any one who has any suggestions to offer, please write to Earl Hodgkins, executive secretary.

On a more personal note, I wish to present my wife, Gilberte. [Applause]

And my son, Erich. [Applause]

With your help, I am looking forward to a productive year for the Association and an enjoyable one for me.

Before we adjourn, I would like to remind all members of the Board of Direction, including the retiring members and those newly elected, and all the members of the General Convention Arrangements Committee, that we will have a joint luncheon together in the Victorian Room off the lobby of this hotel immediately following the adjournment of this meeting. This will be followed by the post Convention meeting of the Board of Direction in Private Dining Room 9 on the third floor.

Before closing the 67th Annual Convention, may I ask if there is any further business to come before the meeting?

R. D. SHELTON: May I have the podium, please? For those who don't know me: I am not an engineer. I am the operating vice president of the Santa Fe Railway, R. D. Shelton.

I believe this meeting is scheduled to come to a close at 12:40, which gives me very little time to tell all I know about Hal. I have known him for 40 years. Some of what I know, I don't know whether he would want told or not, so I will omit that.

It is a pleasure for me to be here with you. I am sorry I didn't get to spend more time at your meetings. It is a great organization; it does a great deal of good. It is through exchange of knowledge, as you do in your organization, that we grow and become more efficient, which is very important in these days of rising labor and material costs.

I think too, it is a great honor to the Santa Fe Railway that Hal makes the fourth Santa Fe president of your Association. The first, I believe, was W. B. Storey, who for many years was president of the Santa Fe. When I went to work, he was still operating vice president. I was far removed from him, because I was a little telegraph operator and train dispatcher down in Texas. But the paths of the other Santa Fe presidents of the AREA—Tom Blair and Rudy Beeder and Hal Wilson—and mine have crossed over a great portion of this railroad in different capacities.

I enjoyed the picture of the D&RGW construction. The thought struck me: how amazing it is what an engineer can do when you give him enough money.

Now it says here that Hal was born at Rockwall, Tex., on January 12, 1904, which was not far, measured in Texas distances, from where I was born only six months before. In 1946, he married his charming wife, Gilberte. And charming she is, because I know her quite well.

I came to Chicago just a month before Hal did and my family was still in Los Angeles. On January 1, now, all Texans have to have blackeyed peas because that gives them good luck throughout the year. That January 1, I tasted blackeyed peas cooked French style, and I have to say they were very good. I didn't know there was any other way to cook them except with salt pork.

Now I am married to a Czech woman who cooks them in chicken broth. And Gil, I know, is going to make a very good companion to Hal in his position here. She has a heart of gold, as I found out when my wife died. And of course, as he has said, he has a son, who is a brilliant child, I know.

Hal entered the Santa Fe service as a mail clerk, after attending Texas University at Amarillo, Tex., on June 5, 1922, and entered the engineering department at Wellington, Kan., on the 20th of the next month. He returned to the University of Texas in September 1924 and came back to the Santa Fe at Amarillo as rodman on June 6, 1925. He then occupied various positions in our engineering department, including a stint as resident engineer of construction on the line running between Amarillo and Boise City, Okla. in 1931.

He was made division engineer at Las Vegas, N. M., in July of 1940, a position he occupied until he entered the U.S. Army as a captain of the 713th Railway Operating Engineers. He rose to the rank of lieutenant colonel; served in Africa, Italy, France and Germany, returning to the position of division engineer at Las Vegas on October 1, 1945.

In October, 1946, he was made district engineer with headquarters at Los Angeles, was transferred to the same position at Topeka, Kans., in March of 1951, became chief engineer of our Eastern Lines with headquarters at Topeka on August 1, 1956 and was transferred to Chicago on October 1, 1959 in his present position of assistant chief engineer system.

Now in the course of your career, things happen to you. Sometimes they are amusing. They tell a story that while he was working as rodman at Amarillo a good many years ago, Hal attempted to climb over a fence at a corner post. A staple gave way resulting in an alleged tear. The post was of cedar. The head of our timber department, Lauress Collister, says the true name is *Juniperus Virginiana*. On another occasion, down on the Slaton Division where he was working as transitman, he had trouble stabilizing his tripod on a virtually new tie and noticed that it was walnut, thus causing him to wonder why a beautiful piece of wood like that would end up as a tie.

Now the head of the gavel I am about to hand Mr. Wilson is made from the fence post; the handle of the gavel is from the black walnut tie.

Now Texas make big things because they are big people, and we wanted him to sound a Texas-size alarm when he bangs this gavel.

So Harold, it gives me a great deal of pleasure to present this to you.

[A huge gavel was presented to President Wilson.]

[Laughter and applause]

Mr. Shelton: Well what are you going to say about it?

President Wilson: Thank you. Didn't you have a bigger one?

Mr. Shelton: It says on here:

"To H. E. Wilson, President AREA, 1968–1969."

Of course, after he has wielded this one, he may become a little tired, so in this box, or casket as it is called, I don't know why, is another gavel. Now this gavel, this small gavel, is made of black walnut and came from the same tie. The box and sounding board for it are from a birch tie that was adjacent to the black walnut tie. Its hard surface also contributed to Mr. Wilson's inability to stabilize the transit.

Congratulations, I know you will do well in your new position.

[The small gavel was presented to President Wilson.]

President Wilson: Thank you very much, Mr. Shelton.

Before closing the 67th Annual Convention may I ask if there is any further business to come before the meeting?

If not, I shall use this beautiful gavel which has been presented to me and declare this 67th Annual Convention of the American Railway Engineering Association and 1968 Annual Meeting of the Engineering Division, Association of American Railroads, adjourned.

[The meeting adjourned at 12:40 o'clock]

Allen Rutherford Wilson
1877-1967

Allen Rutherford Wilson, past president of the American Railway Engineering Association and retired engineer of bridges and buildings of the Pennsylvania Railroad, died at Lansdowne, Pa., on May 3, 1967, at the age of 90.

Mr. Wilson became a member of the Association in 1924 and gave generously of his time and talents in the advancement of its objectives, particularly in the field of steel structures, until his retirement from railway service in 1947. Of special

A. R. Wilson

note was his identity with Committee 15—Iron and Steel Structures, of which he was chairman from 1929 to 1934. Mention should also be made of his work as chairman of the Committee on Clearances from 1929 to 1945. During those 16 years he labored earnestly to stress the importance of considering the cost of alterations and replacement of bridges whenever proposals were made for the introduction of new equipment involving greater widths or heights, or both. This was in many ways a thankless task in which he was beset with many frustrations.

The circumstances attending his attainment of the presidency of the AREA were unique in that he was elected vice president without ever having been elected a director. Instead, he was appointed a director by the Board of Direction to fill a vacancy on the Board resulting from the death of E. A. Hadley on November 11, 1932, and before his term was completed he was nominated for the office of vice president.

His terms as vice president and president (March 1934 to March 1937) were concurrent with an aroused interest in physical research on the part of railway managements which, after a modest start with the inception of the investigation into the causes of internal transverse fissures in rails in 1931, led to the development in the early 1940's of a comprehensive program of engineering research and eventually to the establishment of the AAR Research Center on the grounds of the Illinois Institute of Technology at Chicago. In the meantime, an organization for the conduct of research within the AAR was experiencing growing pains and much of the ground work for the creation of the office of research engineer of the AAR Engineering Division, effective on January 1, 1938, was carried on while Mr. Wilson was president of the AREA and chairman of the AAR Engineering Division.

There is no doubt that his presence on the Board of Direction afforded him an especially favorable opportunity to exert an influence in promoting the project being advanced by the Committee on Iron and Steel Structures for a comprehensive investigation of impact stresses in railway bridges. After funds for this purpose were authorized by the Association of American Railroads, Mr. Wilson was among those recruited from that committee to serve on the new Committee on Impact, which was organized to study and interpret the test results as they became available during investigations.

Allen Rutherford Wilson was born at Bordentown, N. J., on January 15, 1877, the son of William Henry Wilson and Rebecca A. (Black) Wilson. He attended the public schools of Bordentown and the State Normal School at Trenton, N. J., and was graduated in 1896 from the mechanical engineering course of Drexel Institute in Philadelphia, Pa. Mechanical engineering, specifically machine design, occupied his primary attention during the early years of the three decades of engineering experience that was to prepare him for advancement to engineer of bridges and buildings of the Pennsylvania Railroad, a position normally associated with the structural branch of civil engineering.

Upon leaving Drexel Institute, he was employed for some 21 months as a mechanical draftsman for the Pedrick & Ayer Company, a manufacturer of machine tools in Philadelphia, followed by 18 months in a like position with the New Jersey Steel & Iron Company in Trenton. In January 1900 he was employed by the American Bridge Company, serving as a representative of the mechanical department during the construction of the Trenton plant.

Mr. Wilson entered the employ of the Pennsylvania Railroad in July 1902 in the office of the engineer of bridges and buildings, where he was engaged for a number of years in the design of drawbridges, turntables, transfer tables and other structures involving the use of heavy machinery. He was advanced to assistant engineer in March 1920 and two months later to assistant engineer of bridges. His promotion to engineer of bridges and buildings occurred in March 1927.

Upon becoming a member of the AREA in 1924 he was assigned to the Committee on Iron and Steel Structures and was appointed vice chairman of the committee in 1928 and chairman in 1929. He was elected Member Emeritus by the members of the committee when this class of membership was established in 1953.

During his term as chairman, the committee carried out a complete revision of the Specifications for Steel Railway Bridges, a most exacting task involving many changes to keep abreast with the "advances in the art" as well as revisions of the text in those passages where experience in application had indicated opportunities for differences in interpretation. To inform members of the Association of the advances in engineering knowledge upon which many of the revisions were founded, various members of the committee prepared monographs for publication in the AREA Bulletins and Proceedings. This entailed an enormous amount of work on the part of the committee, but created a favorable climate for the adoption of the new specifications.

Mr. Wilson was chairman of the Conference Committee on Welded Highway and Railway Bridges of the American Welding Society, which developed the first authoritative specifications for such structures. It was due to his leadership in the application of welding to railway structures that the Pennsylvania Railroad attained an advanced position in the use of all-welded steel bridges.

In his position as head of the bridge and building department of the Pennsylvania, Mr. Wilson took great pride in his organization and maintained a personal interest in the individual members of his staff, making every effort to improve their usefulness and to aid them in advancing in their professions. To this end, he was always generous in imparting to others the knowledge he had gained in his years of experience in structural engineering. He was truly an inspiring leader and earned the loyalty and friendship of his associates.

As a committee chairman he exercised leadership without any show of pressure. In the conduct of meetings he could stimulate discussion while saying little himself. He encouraged initiative on the part of the members and was careful to give credit where credit was due.

Past President Wilson was also a member of the American Society of Civil Engineers, becoming a Member in 1920, a classification that was changed to Fellow in 1959. He always maintained a genuine interest in the affairs of his home community of Lansdowne. He served on the Board of Deacons of the Lansdowne Baptist Church for 50 years and took an active part in various other community and neighborhood groups. He served for many years as a director of the Federal Savings and Loan Association of Lansdowne and continued his active interest in that organization after his retirement.

Allen Rutherford Wilson was married on September 3, 1898, to Miss Eva Taylor of Bordentown and to this marriage, which was in its 69th year at the time of his death, came five children—Grace, Helen, Harold, Edythe and Dorothy.

W. S. Lacher, *Chairman,*
G. M. O'Rourke
B. R. Meyers
J. E. South
Committee on Memoir

Elzear Joseph Brown
1900-1967

The end of the activities of a devoted and loyal member and past president of the American Railway Engineering Association came with the death of Elzear Joseph Brown on January 3, 1968, at the age of 67. When he retired from active railroad service on June 1, 1967, he was assistant to vice president—operations, Burlington Lines, Chicago.

Mr. Brown joined the American Railway Engineering Association in 1939, and from that time forward a true record of his labors on behalf of the Association would be long indeed. His AREA committee service included Committee 22—

E. J. Brown

Economics of Railway Labor, 1940–1968; Committee 5—Track, 1945–1959; and Committee 31—Continuous Welded Rail, 1952–1968. He was elected a director of the Association in 1955, second vice president in 1958, first vice president in 1959 and president in 1960. He became a Life Member upon retirement.

From an administrative standpoint, Mr. Brown was particularly well qualified to direct the affairs of the Association and to preside over its 1961 convention, having been previously president of the Maintenance of Way Club of Chicago for the year 1936–1937, and president of the Roadmasters and Maintenance of Way Association, 1946–1947.

All sessions of the 1961 AREA Convention were held at McCormick Place, Chicago's $35 million Lakefront Exposition Center, completed only a few weeks before the convention, and subsequently—in 1967—destroyed by fire.

Mr. Brown was also an active participant in the work of the Association of American Railroads. This included service on the Detector Car Committee 1955–1967, serving as chairman 1958–1967; and the General Committee on Waterway

Projects 1962–1967. He also served on the General Committee of the AAR Engineering Division 1955–1963, as vice chairman of the division 1958–1960 and as chairman of the division 1960–1961.

Perhaps his largest field of influence is reflected in the recommendations and conclusions of Committee 22—Economics of Railway Labor, on which he served for 28 years. He traveled great distances and gave of his valuable time to attend committee meetings wherever there was work being done with men and machines, and his practical opinions were valued by everyone.

Past President Brown was responsible for much of the policy that shaped the growth of the Association in recent years. His influence, foresight and determination brought extensive and valuable ideas to the Association, in which he maintained an active interest until the final hours of his life. It was a rare stroke of fortune that combined his talents and energy with the Association's growing needs. A great source of strength has been lost to the AREA and its members, and to the railway engineering profession, as it is not in the nature of things for another "E. J." Brown to enter upon the scene. He possessed a sympathetic, kindly, and generous nature but none doubted his integrity or unwavering courage in the furtherance or defense of that which he conceived to be right in railroad engineering and maintenance of way and structures. He had a keen sense of humor, which endeared him to his many friends, associates and co-workers. And he had a ringing and contagious laugh, which brightened many an occasion and lightened many a "too serious" situation.

Mr. Brown was born on December 1, 1900, at St. Joseph, Missouri. He attended Christian Brothers College at St. Joesph and St. Patricks Academy in Chicago. Ever devout and faithful in his religious life, he was a member of St. Francis Xavier Roman Catholic Church at La Grange, Ill.

Past President Brown is survived by his widow, Alice; two sons, John and James; a sister, Mary Rose Casey; a granddaughter, Jacqueline; a niece, Mary Donna Casey; and a brother, the Reverend John F. Brown. Another brother, the Reverend Donald Brown, preceded him in death. Members of the American Railway Engineering Association extend to Mr. Brown's family their sincere sympathy in and understanding of their great loss, and express their desire to share in treasuring his memory.

G. M. O'Rourke, *Chairman*
R. H. Beeder
G. M. Magee
N. D. Howard
Committee on Memoir

AREA Publications—Price List

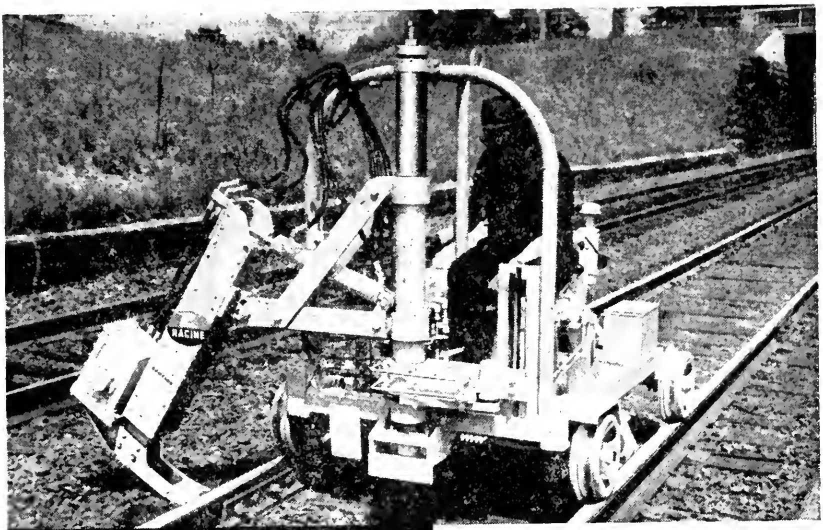
The following include some of the Association publications available from the secretary's office on order. Prices shown are for Members only. Prices for non-members can be obtained from Association Headquarters.

	Member Price
Manual of Recommended Practice, complete in 2 volumes, including binders (first copy)	$25.00
Extra binders, each	5.00
Annual Supplements (first copy)	varies

Separate Chapters

1—Roadway and Ballast	2.00
3—Ties	.50
4—Rail	1.00
5—Track	1.00
6—Buildings	2.00
7—Wood Bridges and Trestles	1.25
8—Masonry	1.25
9—Highways	.75
11—Engineering and Valuation Records	1.50
13—Environmental Engineering (formerly Water, Oil and Sanitation Services	1.25
14—Yards and Terminals	1.25
15—Iron and Steel Structures	1.25
16—Economics of Railway Location and Operation	1.00
17—Wood Preservation	.75
18—Electricity (AAR Electrical Manual, $23.00 Complete with binder. Separate Sections available, prices on request)	
20—Contract Forms	1.50
22—Economics of Railway Labor	.75
25—Waterways and Harbors	.50
27—Maintenance of Way Work Equipment	.75
28—Clearances	.50
29—Waterproofing	.50
Flexible-cover, loose-leaf binder for separate chapters, each	.50

Portfolio of Trackwork Plans—138 plans, 8 sheets of specifications, 5 sheets definitions of terms, complete with leatherette cover	15.00
Instructions for Care and Safe Operation of Welding and Grinding Equipment—23 pages, flexible cover	.30
Specifications for Steel Railway Bridges (fixed spans)—70 pages, flexible cover	1.00
Specifications for Movable Railway Bridges—73 pages, punched sheets	1.00
Structural Fatigue and Steel Railroad Bridges—Proceedings of AREA Seminar, 156 pages, flexible cover	2.00



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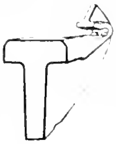
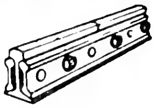
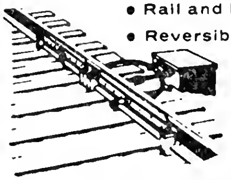
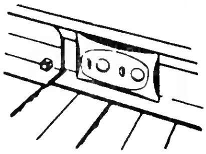
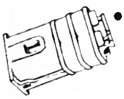
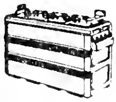






ROOTS AND LOADS TIES

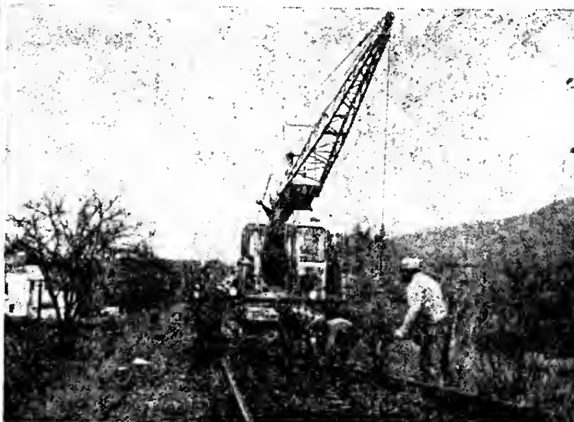
SPEED SWING

MODEL 441

Developed and Built
for Railroad Maintenance

180° BOOM SWING

DOES ALL JOBS!



LAYING STANDARD RAIL

LAYING WELDED RAIL

9' WIDE TRACK CLEANING BUCKET*

CUTS MAINTENANCE COSTS

12 FAST CHANGE ATTACHMENTS

- Forks
- 1¼ Cu. Yd. Bucket
- Tote Hook
- 18' Boom Extension
- Fork Tie Baler
- Track Cleaning Bucket
- Back Hoe
- Clamshell
- Back Filler Blade
- Pull Drag Bucket
- 4 Cu. Yd. Snow Bucket
- Pile Hammer

Optional Attachment
Flanged Wheels, Hydraulically Controlled

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RAILROAD DIVISION
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80 Years of Service
to the Railroad Industry

Report of the Executive Secretary

March 1, 1968

To the Members:

The year 1967 was a great success for the American Railway Engineering Association, from nearly every aspect. The brighest light is the level of AREA membership. Last year, I reported that the downward trend in membership had been reversed. This year, I am pleased to report that our membership soared to the highest level in the Association's 69-year history.

For the third straight year, the demand for the Association's publications was unbelievably high, particularly for the Manual of Recommended Practice for Railway Engineering and the Portfolio of Trackwork Plans. Furthermore, from the orders received during the last 2½ months, it looks like this demand will continue for the fourth consecutive year.

Other factors involved in the Association's forward progress during 1967 include its third highly successful Regional meeting and the interest in and activities of its 23 technical committees, both of which remain at record high levels.

However, in spite of all this bullish atmosphere, there is one big black cloud in the bright Association sky. What else but finances—and don't we all have problems in that area of our personal lives today. Now, don't jump to conclusions; the financial position of the Association is sound but it is in the process of eroding, and if erosion is not halted, it can endanger an entire structure. The Treasurer's report has more to say about this problem, so suffice it for me to say that the Board of Direction already is considering corrective action, and that this action will attack the problem from more than one direction.

Your officers and directors are hard working and dedicated men, who spend many hours each year furthering the interests of the Association and industry they serve. Furthermore, they do not hesitate to make revolutionary decisions when investigation and analysis has proven that such is necessary or desirable to keep the Association on a forward, dynamic course. These men deserve the fullest support and admiration of the membership.

COMMITTEES OF THE BOARD OF DIRECTION

1967–1968

Executive Committee

T. B. Hutcheson (Chairman), H. E. Wilson, H. M. Williamson, A. V. Johnston, J. M. Trissal

Assignments

M. S. Reid (Chairman), H. E. Wilson, C. Neufeld, H. W. Kellogg, J. M. Salmon, Jr.

Personnel

D. H. Shoemaker (Chairman), J. B. Clark, C. Neufeld, F. H. McGuigan, R. M. Brown

Publications

H. M. Williamson (Chairman), D. H. Shoemaker, J. A. Rust, F. H. McGuigan, J. M. Salmon, Jr.

Manual

G. V. Guerin (Chairman), H. W. Kellogg, J. A. Rust, J. B. Clark, E. H. Waring

Membership

J. B. Clark (Chairman), H. M. Williamson, M. S. Reid, A. V. Johnston, E. Q. Johnson

Finance

H. E. Wilson (Chairman), J. M. Trissal, M. S. Reid, G. V. Guerin, R. M. Brown

Research

R. H. Beeder (Chairman), A. V. Johnston, D. H. Shoemaker, H. W. Kellogg, E. H. Waring

Regional Meetings

F. H. McGuigan (Chairman), J. A. Rust, C. Neufeld, E. Q. Johnson

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1968–1969

Executive Committee

H. E. Wilson (Chairman), H. M. Williamson, J. B. Clark, J. M. Trissal, T. B. Hutcheson

Assignments

J. M. Salmon, Jr. (Chairman), F. H. McGuigan, R. M. Brown, W. R. Bjorklund, S. A. Cooper

Personnel

C. Neufeld (Chairman), F. H. McGuigan, R. M. Brown, E. H. Waring, J. F. Piper

Publications

H. M. Williamson (Chairman), T. B. Hutcheson, F. H. McGuigan, J. M. Salmon, Jr., W. R. Bjorklund, J. F. Piper

Manual

J. B. Clark (Chairman), T. B. Hutcheson, H. W. Kellogg, E. H. Waring, C. T. Popma, D. V. Sartore

Membership

E. Q. Johnson (Chairman), H. M. Williamson, C. Neufeld, S. A. Cooper, D. V. Sartore

Finance

H. E. Wilson (Chairman), J. M. Trissal, R. M. Brown, J. F. Piper, D. V. Sartore

Research

R. H. Beeder (Chairman), H. W. Kellogg, E. Q. Johnson, E. H. Waring, C. T. Popma

Regional Meetings

C. T. Popma (Chairman), C. Neufeld, W. R. Bjorklund, S. A. Cooper

1967 Convention

The 66th Annual Convention of the AREA and the 1967 Annual Meeting of the AAR Engineering Division were held on Thursday and Friday, March 9 and 10, at the Conrad Hilton Hotel, Chicago. The Convention was one full day shorter than the normal 2½ days because when the 1967 meetings were planned—and up to the day the meeting began and beyond—the second American Railway Progress Exposition had been scheduled for the entire week of October 8 and the AREA and ED also planned to hold a one-day Membership meeting, as it did in 1963, during the Exposition. However, the Exposition was cancelled as the result of the destruction of McCormick Place by fire in January 1967.

A total of 948 men registered their attendance—561 railroad members and guests and 387 non-railroad members and guests. In addition, 156 wives of AREA members and guests took part in the activities planned for the ladies.

One of the features of the Convention was the Keynote Address, at the Opening Session, by R. R. Manion, vice president, Operations and Maintenance Department, AAR, on "Organizing for Progress." Another was the Annual Luncheon Address by W. A. Johnston, chairman of the Board, Illinois Central Railroad. His talk was entitled "Full Speed Into the Future." The remainder of the program, as usual, consisted of the reports of each of the Association's 22 technical committees, five committee-sponsored special features and the new AAR motion picture "New Directions in Modern Railroading."

Regional Meeting Held in Central Southwest

The third Regional Meeting was held on November 7, 1967, at the Marriott Motor Hotel, Dallas, Tex. A total of 216 men—99 AREA Members, 7 Associate Members, 81 non-member railroad men and 29 non-member, non-railroad guests—attended and heard 9 featured speakers, including G. Rodriguez, assistant to general manager track and structures, National Railways of Mexico, who spoke on "Problems in Construction of Chihuahua & Pacific Railway." The luncheon speaker was J. H. Lloyd, vice president, operations, Missouri Pacific Railroad.

The meeting was planned and directed by AREA Director F. H. McGuigan, assistant engineer of structures, Missouri Pacific. He was assisted by a local arrangements committee headed by R. E. Frame, chief engineer, Texas & Louisiana Lines, Southern Pacific Company.

MEMBERSHIP

When the 1967 membership statistics were compiled on January 31, 1968, the traditional end of the membership year, it was found that a new record had been established. The total was 3421 members of all classes, 119 more than the level on January 31, 1967.

Thus, the dedicated efforts of the officers, directors and members, including chief engineering and maintenance officers of railroads, has definitely reversed the downward trend in AREA membership. This outstanding effort merits a loud and sincere "well done."

However, in the next breath we must request your continued good offices in not only maintaining this level of membership but pushing it even higher. The average level of attrition each year still approaches 250, even though it fell to what may be a record low level in 1967. There are many railroad officers in many departments and job classifications who would benefit from AREA membership and in turn advance the vital work of AREA by contributing a portion of their time, experience, knowledge and talents to its object, the "advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways."

Membership

(Membership year extends from February 1 to January 31)

	Membership Year 1966	*1967*
Members as of February 1, 1966 (beginning of Membership Year)	3307	
Members as of February 1, 1967 (beginning of Membership Year)		3302
New Members during year	186	276
Reinstatements during year	46	33
Gain or loss in Junior Members	— 1	— 8
	3538	3603
Deceased during year	53	43
Resigned during year	45	44
Dropped during year	138	95
	236	182
Net gain or loss	— 5	+119
Membership January 31, 1967 (end of Membership Year)	3302	
Membership January 31, 1968 (end of Membership Year)		3421

Membership Classification by Years

(For each of the membership years shown, the year begins on February 1, and ends on January 31, of the following year)

	1960	*1961*	*1962*	*1963*	*1964*	*1965*	*1966*	*1967*
Life	474	490	489	465	449	457	446	434
Member	2554	2467	2434	2573	2540	2516	2528	2665
Associate	288	301	261	270	267	268	263	265
Junior	91	89	77	90	76	66	65	57
Totals	3407	3347	3261	3398	3332	3307	3302	3421

Student Affiliates

Not included in the foregoing tabulations are the Student Affiliates enrolled in the Association on college campuses. At the end of the 1967–68 academic year 46 students from 21 different campuses had affiliated with AREA, compared with 56 Student Affiliates on 31 campuses one year earlier.

From late 1960, when the Student Affiliate program was started, to the end of the 1967–68 academic year, the Association had enrolled a total of 236 on 59 different college and university campuses in the United States and Canada.

Two Past Presidents Die in 1967 Association Year

From March 1, 1967, to February 29, 1968, 47 members died, 8 less than in the previous Association year, but 6 more than two years ago. These losses are listed immediately following this report.

Unfortunately, however, two of the deceased were past presidents—**A. R. Wilson** (M'24), president 1936–37, and **E. J. Brown** (M'39), president 1960–61. Mr.

Wilson, who died on May 3, 1967, at the age of 90, was retired engineer bridges and buildings, Pennsylvania Railroad. He retired on January 31, 1947. Mr. Brown died on January 3, 1968, at the age of 67. He retired on June 30, 1967, as assistant to vice president—operation, Burlington Lines.

A number of other deceased members are worthy of special note, either for the prominent positions they had attained or for the many years they had devoted to AREA committee service. They are: **N. C. L. Brown** (A'27), retired consultant, General Railway Signal Company, member of Committee 14—Yards and Terminals, 1929–1956; **H. R. Duncan** (M'28), retired superintendent of timber preservation, Chicago, Burlington & Quincy, member of Committee 3—Ties and Wood Preservation, and its predecessors, Committee 3—Ties, and Committee 17—Wood Preservation; 1929–1964, being Member Emeritus of present Committee 3 at the time of his death; **W. H. Edwards** (M'21), retired president, Lehigh & New England; **A. S. Haigh** (M'32), retired signal engineer, New York Central, member of Committee 9—Highways, 1936–1953; **K. H. Hanger** (M'10), retired chief engineer, Missouri–Kansas–Texas, member of Committee 12—Rules and Organization, 1912–1915; Committee 2—Ballast, 1923–1928; Committee 22—Economics of Railway Labor, 1936–1938 and 1948–1957, being made a Member Emeritus of Committee 22 in 1959; **W. G. Hulbert** (A'27), retired vice president, Taylor–Wharton Iron and Steel Company, member of Committee 5—Track, 1929–1953; **F. D. Kinnie** (M'19), retired chief engineer, Eastern Lines, Atchison, Topeka & Santa Fe; **H. E. Kirby** (M'30), retired cost engineer system, Chesapeake & Ohio, member of Committee 22—Economics of Railway Labor, since 1935 and of Committee 24—Cooperative Relations with Universities, since 1950, being Member Emeritus of both these committees at the time of his death; **H. C. Murphy** (M'36), retired president, Burlington Lines; **L. T. Nuckols** (M'20), retired chief engineer, Southern Region, Chesapeake & Ohio, member of Committee 3—Ties, 1926–1934, and Committee 4—Rail, 1943–1958, being elected Member Emeritus of Committee 4 in 1962; **H. A. Palmer** (M'15), retired regional manager, Real Estate Department, Canadian National, member of Committee 20—Contract Forms, 1919–1948; **T. M. Pittman** (M'16), retired division engineer, member of Committee 9—Highways, 1934–1948, and Committee 27—Maintenance of Way Work Equipment, 1932–1957; **L. H. Powell** (M'27); retired chief engineer, Coast Lines, Atchison, Topeka & Santa Fe; **H. M. Shepard** (M'24), retired assistant chief engineer—engineering, Erie, member of Committee 9—Highways, 1927–1948, and Committee 16—Economics of Railway Location and Operation, 1931–1959; **H. E. Silcox** (M'20); retired assistant engineer water supply, Chesapeake & Ohio, member of Committee 13—Environmental Engineering (formerly Water, Oil and Sanitation Services), since 1927, being Member Emeritus at the time of his death; **A. W. Smith** (M'24), retired bridge engineer, Canadian National, member of Committee 8—Masonry, 1925–1940; **F. X. Soete** (M'17), retired purchasing agent, New York, Ontario & Western, member of Committee 11—Engineering and Valuation Records, 1929–1939; **H. M. Tremaine** (M'22), retired district engineer, Northern Pacific, member of Committee 1—Roadway and Ballast, 1943–1951; Committee 3—Ties, 1927–1932; and Committee 16—Economics of Railway Labor, 1933–1944; **L. F. Van Hagan** (M'11), retired professor of railway engineering, University of Wisconsin, member of Committee 15—Iron and Steel Structures, 1913–1920; **R. E. Wachter** (M'20), retired assistant engineer, Missouri Pacific, member of Committee 13—Water, Oil and Sanitation Services, 1934–1954; **V. R. Walling** (M'09), retired chief engineer, Chicago & Western Indiana and Belt Railway of

Chicago, member of Committee 9—Highways, since 1931, being Member Emeritus at the time of his death; Committee 11—Engineering and Valuation Records, 1921–1929; Committee 14—Yards and Terminals, 1941–1948; and Committee 25—Waterways and Harbors, 1952–1955; **R. E. Woodruff** (M'16), retired chairman of the Board, Erie, member of Committee 1—Roadway and Ballast, 1921–1937, and Committee 11—Engineering and Valuation Records, 1930–1935.

ACTIVITIES OF COMMITTEE MEMBERS

Personnel of Committees

At the beginning of the 1967 Association year there were 1206 members assigned to 1333 places on the Association's 23 technical committees (including the newly organized Special Committee on Systems Engineering, which later in the year was given full status as a permanent standing committee—Committee 32—Systems Engineering). This compares with 1198 members who occupied 1293 places on the 22 standing committees at the beginning of the previous year.

AREA committees were limited to a maximum membership of 70 and to the number of members from each railroad, depending on the total number of AREA members from a specific railroad. However, to meet the desire of the Association of American Railroads for relatively small AAR committees, there was continued in 1967 the plan adopted by the General Committee, Engineering Division, in 1961, which provides that the chairmen, vice chairmen, secretaries and all subcommittee chairmen—to the extent that they are in the active employ of railroads—alone constitute the official Engineering Division committees within the larger AREA committees. In 1963, a rule was adopted that only members of committees who are in the active employ of the railroads should be chairmen of subcommittees with assignments dealing with railroad or Association policy matters, assignments calling for expenditures on the part of the railroads, or assignments which might occasion dealing with public officials or agencies.

The number of members assigned to committees for 1968, effective with the official roster changes at the end of the 1968 Annual Convention, will be up from 1967. This increase is due to the continued interest in the new Committee on Systems Engineering, which increased its membership from 36 on March 1, 1967, to 55 on March 1, 1968; to an expansion of several of the more popular committees made possible by a decision of the Board of Direction made in November not to count the Associate Members on a committee against the maximum membership of 70, and to an increased interest in committee membership generally. Specifically, 1246 members have been assigned to 1350 places on committees for 1968.

Committee Meetings

To progress their work on assignments the 23 AREA technical committees held a total of 56 meetings during the 1967 Association year, compared with 67 meetings the previous year. As is usually the case, the large majority of these meetings were held in Chicago or at points central to the largest number of committee members. The exceptions were scheduled to permit inspections of facilities, operations or projects which could be seen only by going to those points.

Of the 56 meetings held during the 1967 Association year, 27 were held in Chicago (including the 15 held during the 1967 Convention); 4 were held in Montreal, Que.; 3 each in St. Louis, Mo., and Cleveland, Ohio; 2 each in New Orleans, La., Washington, D. C., Albany, N. Y., and Houston, Tex., and 11 were held in other cities.

The number of meetings held during the year by each committee was dictated by the scope of their work and other considerations. Accordingly, 1 committee held 5 meetings; 1 committee held 4 meetings; 6 committees each held 3 meetings; 14 committees each held 2 meetings; and one committee held 1 meeting. Combined with their meetings, 24 inspection trips were made by AREA committees during the year to see facilities, structures, procedures, projects and operations directly related to their work.

WORK OF COMMITTEES

During 1967 AREA committees worked on 160 assignments, 25 of which were new. As usual, each subcommittee carried out its own studies and investigations independently, or with the cooperation of the AAR research staff.

Many of these subcommittees held their own meetings before, during or after the scheduled meetings of the full parent committees. At the full committee meetings, the subcommittee chairmen reported on the subcommittee's progress on their assignments and discussed any problems with the work with other members of the full committee. This procedure enables the wide knowledge and experience of all the members of AREA committees, from a large number of railroads, to be applied to the studies of the subcommittees. What an outstanding educational experience AREA committee work can be for our younger members! This is perhaps one of the greatest benefits the individual railroads and the railroad industry as a whole derives from the American Railway Engineering Association—assistance in the technical and administrative preparation of their young engineers and supervisors for greater responsibilities—to the extent these people are allowed to participate in AREA general and committee activities.

A large percentage of AREA committee work is directed toward the preparation of progress or final reports for information; toward revising material appearing in the AREA Manual of Recommended Practice for Railway Engineering, the AAR Electrical Manual of Standards and Recommended Practice, and the AREA Portfolio of Trackwork Plans; toward the development of new Manual and Portfolio material; and toward carrying out special projects related to their assignments.

The 1967 statistics show that our committees produced one or more information reports on 86 of their 160 assignments (not including Assignment A). In addition, the committees submitted 16 reports containing Manual recommendations, all of which, for the first time, were published separate from the committee reports in a Manual Recommendation Supplement to one of the regular Bulletins. Furthermore, all 23 committees presented brief "progress" or "status" statements with respect to assignments on which they made no formal report.

Committee 24—Cooperative Relations with Universities, continued its distribution of the AREA Engineer Recruiting Brochure, entitled "The Railroad Industry—A Challenge and Opportunity for Engineering Graduates," Pictorial Railroad Exhibit and information on summer job opportunities on railroads for engineering students. In addition, the committee continued its program of providing speakers from railroad engineering and maintenance of way departments to address engineering groups—civil, transportation, industrial, mechanical and electrical.

During 1968, the committees as a whole will work on 157 Assignments, 18 of which are new.

Classification of Material

The work of AREA committees during 1967 was so diversified and extensive that it is impossible to do other than refer to it in general terms in a report such as this one, as in past years. However, the following is a general categorical classification of the results of this work, as published in the 6 technical Bulletins of the Association and to be presented to the 1968 Convention:

Recommendations pertaining to the development, revision, or deletion of 42 different specifications and recommended practices for inclusion in the AREA Manual and Portfolio, and the AAR Electrical Manual; 62 reports on current developments in engineering practice and design; 10 reports on current developments in systems engineering and the use of computers to solve problems in railway construction, operation and maintenance; 9 reports dealing with economy in the use of labor and the recruiting and training of employees; 3 reports on new and improved power tools, machines, equipment and material; 2 economic and analytical studies; 5 reports on relations with public authorities; 7 reports dealing with statistics and data processing; and 2 bibliographies.

Committee work affecting the AREA Manual included the presentation of 1 specification for adoption; the rewriting or revision of 25 specifications, with or without reapproval; the deletion of 2 specifications; the presentation of 2 tentative new specifications (1 in the Electrical Manual); the tentative revision of 1 specification; the revision or rewriting of 6 recommended practices, with or without reapproval; the tentative revision of 1 recommended practice; the presentation of 1 tentative new recommended practice; the adoption of 2 agreement forms; and the presentation of 1 tentative agreement form.

ASSOCIATION PUBLICATIONS

The 1967 Association year saw greater than normal activity as far as the production of publications is concerned. As in 1966, it was almost unbelievable the way orders poured into the secretary's office during 1967. So great has been the demand for the AREA Manual that it was necessary to reprint it this year, a year ahead of normal. The same was true of the Portfolio of Trackwork Plans. In addition, the supply of Committee 27's Handbook for the Care and Operation of Maintenance of Way Equipment is completely exhausted.

In 1967 the publications of the Association ran pretty much true to form, with one notable exception—all the Manual recommendations submitted by committees for adoption were published in a separate supplement to the December 1967 Bulletin. The AREA News continued to be published bi-monthly; the Bulletin seven times a year, six technical issues and one Year Book issue; and the Committee Assignments Pamphlet published early in April.

The 1967 Supplement to the AREA Manual contained 218 pages (109 sheets) and if promptly and properly inserted gave railroad engineers and supervisors an outstanding tool to assist them in their work.

The Supplement was automatically mailed to all member holders of the Manual who had paid the $1.00 annual Supplement fee. At the same time non-member holders of the Manual were notified of the availability of the Supplement and the price thereof. Continuing the practice started a number of years ago, the secretary's office mailed direct to all committee members, without charge, copies of the 1967 Supplement sheets pertaining to the Manual chapters sponsored by the committee or committees of which they were members. This practice is followed to permit committee members who have purchased separate copies of their committee's Manual chapter to keep them up to date.

There was no Supplement to the AREA Portfolio in 1967.

Again in 1967, Proceedings Binders automatically were furnished without charge to all members who had standing orders for them on file in the secretary's office. This two-post, hard-cover, book-type binder is designed to house all the Bulletins in the publication year, which starts with the September–October issue and ends with the June–July Proceedings issue, with the exception of the March Year Book Bulletin which is not punched for binding since the Directory of Members never has been published in the Annual Proceedings. The June–July Bulletin each year contains the complete proceedings of that year's Annual Convention. Thus, members maintaining libraries of AREA Proceedings now have completely compatible volumes to add to their collection without the duplication of material that previously existed between the Bulletins and Proceedings.

As the 1967 Association year was drawing to a close, another major publication became available. Its title is "Structural Fatigue and Steel Railroad Bridges," by Professors W. H. Munse and J. E. Stallmeyer, both professors of civil engineering, University of Illinois, and F. P. Drew, research engineer of structures, Association of American Railroads. The contents of this book were compiled from the script of a seminar on structural fatigue sponsored by AREA Committee 15—Iron and Steel Structures. The information contained in the book will be of inestimable value to structural engineers and designers and several universities have ordered multiple copies for use in graduate courses in structural engineering.

RESEARCH WORK

Total Allotments for Research, Engineering Division, AAR, Exclusive of Detector Car Development and Leasing Service

1947–1968

1947	234,428	1958	563,709
1948	294,840	1959	353,800
1949	372,457	1960	350,300
1950	294,045	1961	222,000
1951	354,770	1962	223,671
1952	381,400	1963	226,400
1953	364,100	1964	244,500
1954	351,307	1965	264,500
1955	351,653	1966	302,300
1956	365,050	1967	329,414
1957	476,845	1968	329,500

The budget for 1968 Engineering Division research approved by the AAR Board of Directors at its Annual meeting in Chicago on October 13, 1967 is $3,848, or about 1 percent, less than its 1967 counterpart. The total appropriation for 1968 is $382,100 compared with $385,948 for 1967.

Although it is gratifying that the budget is only some 1 percent under the 1967 figure, the approved budget is some 19 percent less than the $470,100 requested from the AAR by the General Committee of the Engineering Division. On the other hand, the total appropriation does cover all of the projects for which money was requested as being the minimum amount necessary to carry forward satisfactorily the 1967 research work.

To simplify accounting procedures the entire appropriation is not subdivided into each individual project as in past years; accounts will be maintained separately only between Engineering Division Research Projects and Detector Car Development.

The Research Department will progress individual projects for AREA-ED Committees, as they have done in the past, in accordance with the recommendations of the Engineering Division Research Committee and the AAR Research Consulting Committee. These projects are as follows:

List of Projects Included In 1968 Approved Engineering Division Research Budget

Administration
- Research Office

Committee 1—Roadway and Ballast
- Roadbed Stabilization
- Ballast Specification Development

Committee 3—Ties and Wood Preservation
- Further Development of Prestressed Concrete Ties
- Termite Control Investigation
- Anti-Splitting Devices for Ties
- Wood Deterioration in the Presence of Metal

Committee 4—Rail
- Investigation of Failures in Rail
- Rail Failure Statistics
- Insulated Rail Joint Development
- Shelly Spots and Head Checks
- Metallurgical Effects of Rail Cropping Methods
- Semi-Automatic Welding of Rail Batter and Burns

Committee 5—Track
- Prestressed Concrete Crossing Frog Support
- Specification Development for Tie Plate Fastenings and Tie Pads for Wood and Concrete Ties
- Slide Plate Lubrication
- Bridge Rail Expansion Joints

Committee 7—Wood Bridges and Trestles
- Strength of Timber Stringers
- Quantitative Analysis of In-Place Treatment of Timber Bridges
- Non-Destructive Testing of Wood

Committee 8—Masonry
- Butyl Rubber Waterproofing Membrane
- Repeated Local Strength of Concrete Under High Speed Impacts
- Strength of Prestressed Concrete Bridge Ties

Committee 14—Yards and Terminals
- Weighing Cars in Motion
- Rollability of Freight Cars
- Specification for Belt Conveyor Weighing

Committee 15—Iron and Steel Structures
- Protection of Steel Surfaces
- Synthetic Materials for Sliding Bridge Bearings

Committee 16—Economics of Railway Location and Operation
- Feasibility of Determining Track Maintenance Requirements by Digital Computer Analysis

Committee 24—Cooperative Relations with Universities
- Student Research Grants

Committee 30—Impact and Bridge Stresses
- Timber Bridges
- Steel Bridges
- Concrete Bridges
- Calculation of Bridge Stresses by Digital Computer

Committee 31—Continuous Welded Rail
- Butt-Welding of Rails
- Anchorage of Continuous Welded Rail

Joint Committee on Relation Between Track and Equipment
- Relation of Wheel Load to Wheel Diameter

Dynamic Action of Piggyback and New Types of Freight Cars

Relation of High Center of Gravity and Heavy Loading to Derailing and Roll Action Including Some of the High Capacity Cars of Recent Design

Effect on Curved Track of Diesel Locomotive with Three and Four-Axle Trucks

Train Resistance for New Types of Equipment and High Speed Operation

Board Committee on Research

Methods of Rail Flaw Detection

Computer Atmospheric and Electronic Collaboration

General Electrical Laboratory and Instrumentation

Detector Car Development

Further Development of Detector Car Testing—Road-Rail Units and Ultrasonic Units

Technical Services

General Technical Services

LOOKING AHEAD

At the present time, four future Convention dates and locations have been definitely established. They are:

1969—March 10–12, Pick-Congress Hotel, Chicago
1970—March 23–25, Palmer House, Chicago
1971—March 15–18, Sherman House, Chicago
1974—March 19–21, Sherman House

Dates satisfactory to AREA are in the process of being worked out by the executive secretary and the Palmer House sales manager, in line with the policy established two years ago by the Board of Direction that the Palmer House is the official AREA Convention hotel when satisfactory dates are available or can be cleared. Obviously, 1969, 1971 and 1974 depart from that policy. The former was established before the policy was developed; the latter two because satisfactory dates could not be made available by the Palmer House. The dates and location of the 1971 and 1974 Conventions were established to accommodate the Railway Engineering—Maintenance Suppliers Association because its officers had reserved space in either the International Amphitheatre or the rebuilt McCormick Place for exhibits in those years. This follows the return of REMSA to the 18-month pattern of exhibits, alternating between March and September.

Members can continue to look forward to AREA Regional Meetings, at least as long as they continue to support those held in their general regions, and a few of them are willing to pitch in and help make the plans and arrangements for them. The Regional Meetings held thus far, in the Northwest, Southeast and Central Southwest, have proved to be extremely popular and attendance has been over 200 at each one, and has increased to a small extent each year.

So much for the good things of Association life; now let's take a look at some of the harsher things. As reported, our membership level is the highest in the 69-year history of the AREA, but it will not stay there without continued efforts on the part of the officers, directors and members, and chief engineering and maintenance officers as well. A strong AREA can make even greater contributions to railway engineers and railway engineering and maintenance of way and structures than it has in the past. The muscle and sinew of AREA are its members, but without a large quantity and high quality of members, those willing and able to contribute to the work, the Association will have trouble in accomplishing all the work in front of it.

The AREA is in a particularly strategic and advantageous position to make positive and outstanding contributions to the railroad industry, as well as to the railway and civil engineering professions. The Plan of Organization and Rules of Order adopted early last year for the AAR Engineering Division solidified the relationship by formally coupling the Engineering Division to the governing and technical-committee structure of the AREA. However, to realize the potential of the combine, committees, particularly those working in sensitive and strategic areas, must "retool" to be able to handle quickly, efficiently and fully, the assignments submitted to it by the railroad industry, either directly from railroads, from the AREA Board, from the AAR vice president of operations and maintenance, or from other AAR divisions and sections. In many such cases the traditional AREA procedure for working on assignments is too laborious and requires too much time from request to answer. The times in which we live today simply are moving too fast for us not to have expeditious means of handling problems which the industry submits to us for solutions. On the other hand, if railroad management wants fast and full answers it must realize that the answers can be developed only by those engineers on their staffs qualified by training and experience to take the problem and work out practical solutions. This takes time and frequently a certain amount of travel for the individuals concerned. Committees cannot progress assignments satisfactorily if only half of a 10-or-so-man task force or special subcommittee could not attend a vital meeting, or participate in the correspondence leading up to the meeting. Such problems have been extremely vexing in trying to progress some of the special problems now in the hands of a number of AREA-ED technical committees.

The days, weeks, months and years ahead will not be easy for railway engineers and their Association. But, the challenge of problems and obstacles has always spurred dedicated men to overcome them and emerge triumphant. I assure you there is no doubt in the minds of your officers and directors that many such men hold membership in the Association and are already making outstanding contributions to the work of our committees, and stand ready to make even greater contributions if given the opportunity. Furthermore, you may rest assured that the officers and directors will be in the vanguard of all such work and activities.

The slogan used during the 50th Anniversary Year (1949) of the American Railway Engineering Association has never been more appropriate than it is today . . .

"A Past of Achievement—A Future of Opportunity"

Respectfully submitted,

Earl W. Hodgkins,
Executive Secretary.

Deceased Members

(March 1, 1967 to February 29, 1968)

A. G. Boughner (M '05)
Retired Special Engineer, Baltimore & Ohio Railroad, R. D. 3, Confulence, Pa.

E. J. Brown (M '39)
Retired Vice President Operation, Burlington Lines, Chicago, Ill.

N. C. L. Brown (A '27)
Retired Consultant, General Railway Signal Company, 21 Brown's Avenue, Scottsville, N. Y.

G. W. Burpee (M '20)
Partner, Coverdale & Colpitts, 120 Wall Street, New York, N. Y.

L. B. Curtis (M '19)*
Retired Architect, Northern Pacific Railway, 1473 Grantham St., St. Paul, Minn.

W. M. Davidson (M '44)
Railway Consultant, National Capital Commission, 291 Carling Avenue, Ottawa, Ont.

H. R. Duncan (M '28)
Retired Superintendent of Timber Preservation, Chicago, Burlington & Quincy Railroad, 1756 E. Main Street, Galesburg, Ill.

W. H. Edwards (M '21)
Retired President, Lehigh & New England Railroad, Northfield Apts., 1825 Center Ave., Bethlehem, Pa.

L. T. Ferguson (M '63)
System Track Engineer, Union Pacific Railroad, Omaha, Nebr.

A. Foukal (A '35)
Retired Sales Manager, Misc. Steel Products, Republic Steel Corporation, 1105 Mount Vernon Blvd., Cleveland Heights, Ohio

W. E. Fowler (A '20)
Retired Vice President, Youngstown Sheet & Tube Company, 4138 Stafford Rd., Youngstown, Ohio

R. J. Gatewood (M '21)
Retired Division Engineer, Atchison, Topeka & Santa Fe Railway, 1318 No. Washington Ave. Wellington, Kans.

A. S. Haigh (M '32)
Retired Signal Engineer, New York Central System, 8 Cuyler Avenue, Albany, N. Y.

K H. Hanger (M '10)*
Retired Chief Engineer, Missouri-Kansas-Texas Lines, 1010 Scott St., Little Rock, Ark.

Wm. G. Hulbert (A '27)
Retired Vice President, Taylor Wharton Iron & Steel Company, 97 St. Stephens Lane West, Scotia, N. Y.

M. B. Kaufman (M '51)

Retired Division Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, 4612 Grove St., Skokie, Ill.

F. D. Kinnie (M '19)

Retired Chief Engineer, Atchison, Topeka & Santa Fe Railway, Eastern Lines, Fairway Apartments, 600 Wichita, McAllen, Tex.

H. E. Kirby (M '30)

Retired Cost Engineer System, Chesapeake & Ohio Railway, 2870 Roseneath Road, Huntington, W. Va.

H. C. Koeltz (M '24)

Retired Engineer Reproduction Costs, Atlantic Coast Line Railway, 3420 Shamrock Drive, Charlotte, N. C.

R. A. Lariviere (M '60)

Auditor–Property Accounts, Chesapeake & Ohio Railway, Huntington, W. Va.

B. A. MacLean (M '60)

Supervisor Track, Pennsylvania Railroad, Lancaster, Pa.

M. F. Mannion (M '23)

Retired Assistant Comptroller, Bessemer & Lake Erie Railroad, 96 North High Street, Greenville, Pa.

K. R. McLennan (M '31)

Retired Assistant Engineer, Canadian National Railways, 133 Madison Avenue, Tornoto, Ont.

H. C. Murphy (M '36)

Retired President, Burlington Lines, 441 Oak Avenue, Aurora, Ill.

L. T. Nuckols (M '20)

Retired Chief Engineer, Southern Region, Chesapeake & Ohio Railway, 2198 Silver Palm Road West, Boca Raton, Fla. 33432

B. J. Ornburn (M '42)

Assistant Chief Engineer—Structures, Chicago, Milwaukee, St. Paul & Pacific Railroad, Chicago, Ill.

H. A. Palmer (M '15)

Retired Regional Manager, Real Estate Department, Canadian National Railways, 186 Wilson Avenue, Toronto, Ont.

T. M. Pittman (M '16)

Retired Division Engineer, Illinois Central Railroad, 228 Woodlawn Drive, Panama City, Fla.

L. H. Powell (M '27)

Retired Chief Engineer, Atchison, Topeka & Santa Fe Railway—Coast Lines, 1620 Rubio Drive, San Marino, Calif.

R. V. Proctor (A '31)

Retired General Manager, Commercial Shearing and Stamping Company, Bradenton, Fla.

E. H. Reed (A '65)

Lighting Engineer, Revere Electric Manufacturing Company, 7420 N. Lehigh, Niles, Ill.

H. L. Richardson (M '63)

Assistant Division Engineer, Seaboard Coast Line Railroad, Raleigh, N. C.

G. F. Rothwell (M '57)
Engineer of Planning, Western Region, Norfolk & Western Railway, St. Louis, Mo.

W. W. Salisbury (M '59)
Retired Special Engineer, Missouri Pacific Railroad, 403 N. Lawn Avenue, Kansas City, Mo.

H. M. Shepard (M '24)
Retired Assistant Chief Engineer—Engineering, Erie Railroad, 255 New England Highway, Maitland, N. S. W., Australia

H. E. Silcox (M '20)
Retired Assistant Engineer Water Supply, Chesapeake & Ohio Railway, 1214 Nottoway Ave., Richmond, Va. 23227

A. W. Smith (M '24)
Retired Bridge Engineer, Canadian National Railways, 595 Curzon Ave., St. Lambert, Que.

F. X. Soete (M '17)
Retired Purchasing Agent, New York, Ontario & Western Railway, 160 East 48th Street, New York, N. Y.

W. A. Spell (M '10)
Retired Engineer Maintenance of Way, Western Division, Atlantic Coast Line Railroad, 507 South East Street, Greensboro, Ga.

G. G. Thomas (M '21)
Retired Engineer of Bridges, Atlantic Coast Line Railroad, 246 Forest Hills Drive, Wilmington, N. C.

H. M. Tremaine (M '22)
Retired District Engineer, Northern Pacific Railway, Spokane Club, 1002 W. Riverside, Spokane, Wash.

L. F. Van Hagan (M '11)
Retired Professor of Railway Engineering, University of Wisconsin, 2105 Madison St., Madison, Wisc.

R. E. Wachter (M '20)*
Retired Assistant Engineer, Missouri Pacific Railroad, 230 Diane Road, Florissant, Mo.

V. R. Walling (M '09)
Retired Chief Engineer, Chicago & Western Indiana Railroad; Belt Railway of Chicago, 420 Valencia Avenue, Coral Gables, Fla.

H. T. Williams (M '51)
District Engineer, Western Australia Government Railways Commission, Perth, Western Australia

A. R. Wilson (M '24)
Retired Engineer Bridges and Buildings, Pennsylvania Railroad, Lansdowne, Pa.

R. E. Woodruff (M '16)
Retired Chairman of Board, Erie Railroad, 414 South Ocean Boulevard, Delray Beach, Fla.

Report of the Treasurer

December 31, 1967

To the Members:

It was anticipated that the year 1967 would be a poor one financially for the Association, with Disbursements expected to exceed Receipts by $26,110, due primarily to a complete reprinting of the Manual and the Portfolio of Trackwork Plans to replenish depleted stocks of these two Association publications. However, the deficit for the year was actually $22,363.34.

Total Receipts were $4,124 higher than expected, due to Membership Accounts exceeding estimation by $2,200, Manual $1,200 and Track Plans $800. That Manual receipts exceeded estimation was due to the reprinted Manual becoming available at a date that enabled back orders to be filled late in 1967 with resultant higher than anticipated revenue for the year. All other items of receipts slightly exceeded expectations with the exception of Advertising, which was under expectation by some $1,000.

Manual Receipts for 1967 totalled $10,237.88, which again illustrates the high regard in which this AREA publication is held by the entire engineering profession. Total disbursements were $101,087.51, an overexpenditure of only $377.51.

The year 1968 will again, as in 1967, present a problem in Association financing, and will result in a serious unfavorable balance of Disbursements exceeding Receipts. This situation is predicated on the extremely high increase (30 per cent) in the cost of printing Association publications in 1968; increased postal rates; and a general increase in the cost of doing business.

There is little possibility of augmenting Association receipts, except the increasing of the sale price of Association publications to reflect, in part, the rising cost of producing them, and increased membership. Therefore, it is incumbent on all officers and members of the Association to join in an effort to increase AREA Membership, with resultant higher receipts, and to keep to a minimum those members, who, for one cause or another, may relinquish their memberships during the year. And, through the combined efforts of all, to keep to the minimum Association expenditures during the year, especially those of a non-renumerative nature, so that the inevitable loss for the year 1968, with Disbursements exceeding Receipts, may be kept to the lowest amount possible.

Respectfully submitted,

A. B. Hillman, Jr.,
Treasurer.

COMPARISON OF RECEIPTS AND DISBURSEMENTS FOR THE LAST 20 YEARS

	Receipts	*Disbursements*	*Net Gain*
1948	$57,741.00	$ 53,062.00	$ 4,679.00
1949	62,081.00	57,075.00	5,005.00
1950	59,752.00	51,795.00	7,957.00
1951	69,045.00	62,369.00	6,676.00
1952	77,514.00	76,964.00	550.00
1953	73,033.00	82,067.00	9,034.79*
1954	85,748.99	68,003.03	17,745.96*
1955	80,177.21	73,923.18	6,254.03
1956	79,531.11	70,336.17	9,014.04
1957	85,429.31	89,830.57	4,401.26*
1958	81,454.56	77,348.92	4,105.64
1959	80,407.16	80,297.48	109.68
1960	81,138.79	83,978.29	2,839.50
1961	83,461.73	73,410.20	10,051.53
1962	76,097.28	87,344.12	11,246.84*
1963	73,653.48	66,156.99	7,496.49
1964	74,834.81	78,118.66	3,283.85*
1965	81,336.73	73,895.90	7,440.83
1966	84,590.91	80,454.00	4,136.91
1967	78,724.17	101,087.51	22,363.34*

*Deficit.

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDING DECEMBER 31, 1967

Receipts

Balance on Hand January 1, 1967			$155,668.12
Membership Account			
Entrance Fees	$ 2,555.00		
Dues	44,172.95	$ 46,727.95	
Sale of Publications			
Proceedings	$ 1,973.90		
Bulletins	2,385.65		
Manuals	10,237.88		
Track Plans	2,801.05		
Specifications	838.74		
Brochures	34.80		
		$ 18,272.02	
Advertising in Publications		4,970.50	
Convention Registration Fees		1,802.00	
Interest Account on Investments	$ 6,243.55		
Interest Account on Special Account	648.64	6,892.19	
Miscellaneous and Student Affiliate Fees		708.15	
Total		$ 79,372.81	

Disbursements

Salaries	$28,035.24		
Bulletins and Proceedings	21,281.14		
Stationery and Printing	2,733.71		
Rent	1,140.00		
Postage	2,510.00		
Supplies	370.08		
Audit	400.00		
Pensions	6,101.40		
Social Security and Unemployment Tax	1,817.67		
Manual	16,833.14		
Refunds	107.15		
Committee and Officers Expense	1,041.60		
Newsletter	2,831.47		
Annual Meeting	3,385.93		
Student Affiliates	66.00		
Miscellaneous and Professors Expenses	4,677.81		
Track Plans	7,318.80		
Extraordinary	436.37		
Total		$101,087.51	
Excess of Disbursements over Receipts			$ 21,714.70
Balance on hand December 31, 1967			$133,953.42

STATEMENT OF ASSETS

Balance on Hand, January 1, 1967		$155,668.12
Receipts during 1967	$ 78,724.17	
Paid out on Audited Vouchers	101,087.51	
Excess of Disbursements over Receipts	$ 22,363.34	
Less interest on Savings Account	648.64	21,714.70
Balance on hand December 31, 1967		$133,953.42
Consisting of:		
Bonds at cost	$131,715.01	
Cash in Northern Trust Co.	—14,410.24	
Special Deposit in Northern Trust Co.	16,623.65	
Petty Cash	25.00	
		$133,953.42

We have made an examination of the accounts of the American Railway Engineering Association for the year ending December 31, 1967, and found them to be in accordance with the foregoing statement.

C. A. Bick,
C. H. Colby,
Auditors.

GENERAL BALANCE SHEET

	1967	1966
Assets:		
Cash in Northern Trust Co.		
Commercial Account	$(14,410.24)	$ 7,953.10
Special Account	15,975.01	15,406.58
Interest on Special Account	648.64	568.43
Petty Cash	25.00	25.00
Due from Members	65.00	90.00
Due from Sale of Publications	----------	18.00
Due from Advertising	581.20	261.80
Prepaid Postage	212.38	55.17
Furniture and Fixtures	1,000.00	1,000.00
Inventories:		
Publications (estimated)	500.00	500.00
Manuals	12,483.00	1,859.00
Track Plans	893.00	595.00
Binders, Indexes and Chapters	100.00	75.00
Investments (cost)	131,715.01	131,715.01
Interest Accrued on Investments	1,117.56	958.64
Totals	$150,905.56	$161,080.73
Liabilities:		
Members dues paid in advance	$ 725.00	$ 763.50
Surplus	150,180.56	160,317.03
Totals	$150,905.56	$161,080.53

STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS, YEAR 1967

		Commercial Account	Special Account
Cash in Bank, January 1, 1966		$ 7,953.10	$ 15,975.01
Receipts:			
From members, sales of publications, interest, etc.		$ 78,724.17	
Bond Called		10,000.00	
Interest on deposits in Savings Account			648.64
		$ 96,677.27	$ 16,623.65
Disbursements:			
Purchase of Savings Certifications	$ 10,000.00		
Audited Vouchers	101,087.51		
Excess of Disbursements over Receipts		$ 21,714.70	
Cash in Bank December 31, 1967		($14,410.21)	$ 16,623.65

( ) Denotes red figures.

American Railway Engineering Association

CONSTITUTION

Revised to March 8, 1967

Article I

NAME, OBJECT AND LOCATION

1. Name

The name of this Association shall be the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

2. Object

The object of the Association shall be the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

3. Means to be Used

The means to be used for this purpose shall be:

(a) The investigation of matters pertaining to the object of the Association through Study and Research Committees.

(b) Meeting for the presentation and discussion of papers, and for action on the recommendations of committees.

(c) The publication of papers, reports and discussions.

4. Conclusions

The conclusions adopted by the Association shall be recommendatory.

5. Location

The office of the Association shall be located in Chicago, Ill.

Article II

MEMBERSHIP

1. Classes

The membership of this Association shall be divided into five classes: Members, Life Members, Honorary Members, Associates and Junior Members.

2. Qualifications

A. GENERAL

(a) An applicant to be eligible for membership in any class other than that of Junior Member shall be not less than 25 years of age.

(b) To be eligible for membership in any class, or for retention of membership as a Member, an Associate or a Junior Member, a person shall not be engaged directly or primarily in the sale to the railways of appliances, supplies, patents or patented services.

(c) The right to membership shall not be terminated by retirement from active service.

(d) In determining the eligibility for membership in any class, graduation in engineering from a school of recognized standing shall be considered as equivalent to three years of active practice, and satisfactory completion of each year of work in such school, without graduation, shall be considered as equivalent to one-half year of active practice.

(e) In determining the eligibility for Member under Section B (a) of this Article, each year of practical experience in engineering, or in science related thereof, prior to employment on a railway, if such experience were of the same specialized character as the current work of the applicant, shall be considered as equivalent to one year of railway service.

B. Member

A Member shall be:

(a) A railway engineer or officer who has had not less than five years' experience in the location, construction, operation or maintenance of railways and who is employed by a common-carrier railway corporation, by an approved association of railroads or railway engineers or officers, or by a non-common-carrier railway if his primary duties consist entirely or primarily of the location, construction, operation or maintenance of a railway plant and facilities.

(b) A dean, professor, assistant professor, or equivalent in engineering in a university or college of recognized standing, or an instructor or equivalent in such university or college, who, with an engineering degree, has had at least two years' experience in teaching engineering.

(c) An engineer or member of a public board, commission or other official agency who, in the discharge of his regular duties, deals with railway problems.

(d) An editor of a trade or technical magazine who, in the discharge of his regular duties, deals with railway problems, and who has had the equivalent of five years' engineering or railway experience.

(e) A consulting engineer or contractor, or an engineer in their employ, engaged in the engineering, construction and maintenance of railroad-related facilities or an engineer employed by a technical service or research and development organization who has had the equivalent of five years' engineering experience.

(f) An officer or engineer of an engineering or scientific society or association whose aims and objectives are compatible with the aims and objectives of this association.

C. Life Member

A Life Member shall be a Member or an Associate who has paid dues for 35 years, or who has been retired under a recognized retirement plan and has paid dues for not less than 25 years.

D. Honorary Member

(a) An Honorary Member shall be a person of acknowledged eminence in railways engineering or management.

(b) The number of Honorary Members shall be limited to ten.

E. Associate

An Associate shall be:

(a) A member of a railway supply company or association who meets the qualifications of Section 2, Paragraph A (a) and (b).

(b) A person qualified by training and experience to cooperate with Members in the object of this Association, but who is not qualified to become a Member.

F. Junior Member

(a) A Junior Member shall be not less than 21 years of age, shall have had not less than three years' experience in the location, construction, operation or maintenance of railways, and shall be an employee of a railway corporation, or one of the organizations or institutions listed under Section B of this Article, or a railway supply company if he qualifies under Section 2, Paragraph A (b) of this Article.

(b) His membership in this classification in the Association shall terminate at the end of the calendar year in which he becomes 30 years of age.

(c) He may make application for membership other than as a Junior Member at any time when he becomes eligible to do so.

3. Transfers

The Board of Direction shall transfer from one class of membership to another, or may remove from membership, any person whose qualifications so change as to warrant such action.

4. Rights

(a) Members, and Life Members who were formerly Members, shall have all the rights and privileges of the Association. Life Members who were formerly Associates shall continue to have all the rights and privileges of Associates.

(b) Honorary Members shall have all the rights and privileges of the Association except those of holding elective office, provided, however, that Members or Life Members who are elected Honorary Members shall retain all the rights and privileges of the Association.

(c) Associates and Junior Members shall have all the rights and privileges of the Association except those of voting and holding elective office.

Article III

Admission, Resignation, Expulsion and Reinstatement

1. Charter Membership

The Charter Membership of this Association consists of all persons elected to membership before March 15, 1900.

2. Application for Membership

(a) A person desirous of membership in this Association shall make application upon the form provided by the Board of Direction. In the event that Junior Membership is desired, the applicant shall so state.

(b) The applicant shall give the names of at least three Members of this Association to whom personally known. Each of these Members shall be requested by the Executive Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's qualifications for membership.

(c) If an applicant is not personally known to as many as three Members of this Association, the names of well-known persons engaged in railway or allied professional work to whom he is personally known shall be substituted, as necessary, to provide a total of at least three references. Each of these persons shall be requested by the Executive Secretary of the Association to certify to a personal knowledge of the applicant, with an opinion of the applicant's qualifications for membership.

(d) No further action shall be taken upon the application until replies have been received from at least three of the persons named by the applicant as references.

3. Election to Membership

(a) Upon completion of the application in accordance with Section 2 of this Article the Board of Direction through its Membership Committee shall consider the application and make such investigation as it may consider desirable or necessary.

(b) Upon completion of such consideration and investigation, each member of the Board of Direction shall be supplied with the required information, together with the recommendation of the Membership Committee as to the class of membership, if any, to which the applicant is eligible, and the admission of the applicant shall be canvassed by ballot among the members of the Board of Direction.

(c) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (b) of this Article, a two-thirds affirmative vote of the entire Board of Direction shall be required for election.

(d) In the event that an application has been made under the provision of Section 2, Paragraphs (a) and (c) of the Article, a unanimous affirmative vote of the entire Board of Direction shall be required for election.

4. Subscription to the Constitution

An applicant for any class of membership in this Association shall declare his willingness to abide by the Constitution of the Association in his application for membership.

5. Honorary Member

A proposal for Honorary Membership shall be endorsed by ten or more Members of the Association and a copy furnished each member of the Board of Direction. The nominee shall be declared an Honorary Member upon receiving a unanimous vote of the entire Board of Direction.

6. Resignation

The Board of Direction shall accept the resignation, tendered in writing, of any person holding membership in the Association whose obligations to the Association have been fulfilled.

7. Expulsion

Charges of misconduct on the part of anyone holding membership in this Association, if in writing and signed by ten or more Members, may be submitted to the Board of Direction for examination and action. If, in the opinion of the Board action is warranted, the person complained of shall be served with a copy of such charges and shall be given an opportunity to answer them to the Board of Direction. After such opportunity has been given, the Board of Direction shall take final action. A two-thirds affirmative vote of the entire Board of Direction shall be required for expulsion.

8. Reinstatement

(a) A person having been a Member, an Associate or a Junior Member of this Association and having resigned such membership while in good standing may be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

(b) A person having been a Member, an Associate or a Junior Member of this Association and having forfeited membership under the provisions of Article IV, Section 3, may, upon such conditions as may be fixed by the Board, be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

Article IV

Dues

1. Entrance Fee

(a) An entrance fee of $10 shall be payable to the Association with each application for membership other than Junior Membership. This sum shall be returned to an applicant not elected.

(b) An entrance fee of $5 shall be payable to the Association with each application for Junior Member, which sum shall be returned to an applicant not elected. When a Junior Member transfers to the Member or Associate Member class the previously paid $5 entrance fee shall be credited towards the entrance fee for the class to which transferring. However, the Junior Member entrance fee shall not be returnable should the individual resign from the Association or allow his membership to lapse. Neither shall it be applicable to the dues for any year.

2. Annual Dues

(a) The annual dues for each Member and each Associate shall be $15.

(b) The annual dues for each Junior Member shall be $5.

(c) Life Members and Honorary Members shall be exempt from the payment of dues. Life Members desiring to continue to receive the Bulletins and Proceedings of the Association may do so by paying a subscription fee prescribed by the Board of Direction

3. Arrears

A person whose dues are not paid before April 1 of the current year shall be notified by the Executive Secretary. If the dues are still unpaid on July 1, further notice shall be given, informing the person that he is not in good standing in the Association. If the dues remain unpaid by October 1, the person shall be notified that he will no longer receive the publications of the Association. If the dues are not paid by December 31, the person shall forfeit membership without further action or notice, except as provided for in Section 4 of this Article.

4. Remission of Dues

The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member, Associate or Junior Member who, for good reason, is unable to pay them.

Article V

Officers

1. Officers

(a) The officers of the Association shall be a President, two Vice Presidents, twelve Directors, an Executive Secretary and a Treasurer.

(b) The President, the Vice Presidents, the Directors and the two Past Presidents on the Board of Direction shall be Members and shall act as the trustees and have the custody of all property belonging to the Association.

(c) The Executive Secretary and the Treasurer shall be appointed by the Board of Direction.

2. Term of Office

The term of office of the President shall be one year, of the Vice Presidents two years and of the Directors three years. The term of each shall begin at the close of the annual convention at which elected and continue until a successor is qualified. All other officers and employees shall hold office or position at the pleasure of the Board of Direction.

3. Officers Elected Annually

(a) There shall be elected at each annual convention a President, one Vice President and four Directors.

(b) The candidates for President and for Vice President shall be selected from the members or past members of the Board of Direction.

4. Conditions of Re-election of Officers

A President shall be ineligible for re-election, except as provided for in Section 5 (e) of this Article. Vice Presidents and Directors shall be ineligible for re-election to the same office, except as provided for in Section 5 (e) of this Article, until, at least one full term has elapsed after the end of their respective terms.

5. Vacancies in Offices

(a) If a vacancy should occur in the office of President, as set forth in Section 6 of this Article, the senior Vice President shall immediately and automatically become President for the unexpired term.

(b) If a vacancy should occur in the office of the senior Vice President, due to advancement under Section 5 (a) of this Article, or for reasons set forth in Section 6 of this Article, the junior Vice President shall automatically become senior Vice President for the unexpired term.

(c) If a vacancy should occur in the office of the junior Vice President, due to advancement under Section 5 (b) of this Article, or for reasons set forth in Section 6 of this Article, the Board of Direction shall by the affirmative vote of two-thirds of its entire membership, select a junior Vice President from the members or past members of the Board of Direction.

(d) A vacancy in the office of Director, due to advancement of a Director to junior Vice President under Section 5 (c) of this Article, or for reasons set forth in Section 6 of this Article, shall be filled by the Board of Direction by the affirmative vote of two-thirds of its entire membership.

(e) An incumbent in any office for an unexpired term shall be eligible for re-election to the office held; provided, however, that anyone selected to fill a vacancy as Director shall be eligible for election to that office, excepting that such appointee filling out an unexpired term of two years or more shall be considered as coming within the provisions of Section 4 of this Article.

5. Vacation of Office

(a) In the event of the death of an elected officer, or his resignation from office, or if he should cease to be a Member of the Association as provided in Section 2 (B), Article II; Section 6 or 7, Article III; or Section 3, Article IV, the office shall be considered as vacated.

(b) In the event of the disability of an officer or neglect in the performance of duty by an officer, the Board of Direction, by the affirmative vote of two-thirds of its entire membership shall have the power to declare the office vacant.

Article VI

Nomination and Election of Officers

1. Nominating Committee

(a) There shall be a Nominating Committee composed of the five latest living Past Presidents of the Association, who are Members, and five Members who are not officers.

(b) The five Members who are not Past Presidents shall be elected annually for a term of one year, when the officers of the Association are elected.

(c) The senior Past President who is a member of the committee shall be the chairman of the committee. In the absence of the senior Past President from a meeting of the committee the Past President next in seniority present shall act as chairman.

(d) If one or more Past Presidents are unable to act as members of the committee through disability, the President shall have the authority to appoint an equivalent number of eligible next senior Past Presidents to the committee as ordinary members.

(e) If one or more elected members of the committee are unable to act, through death or disability, the President shall have the authority to appoint as replacements an equivalent number of the senior unsuccessful candidates for election to the committee.

2. Method of Nominating

(a) At least three months prior to the annual convention, the Chairman shall call a meeting of the committee at a convenient place, at which nominees for the several elective offices shall be selected as follows:

Office to be Filled	*Number of Candidates to be named by the Nominating Committee*	*Number of Candidates to be elected at the Annual Election of Officers*
President	1	1
Vice President	1	1
Directors	8	4
Nominating Committee	10	5

(b) The nominations for Director shall maintain the territorial balance prescribed in Article VII, Section 1, Paragraph (b), to the maximum extent practicable. In this connection, the nominations for Director shall be predicated, insofar as practicable, on the following three-year repeating pattern of Director positions to ensure adequate territorial distribution:

First Year	Second Year	Third Year
East—2	East—1	East—1
South—1	West—2	South—1
West—1	Canada—1	West—2

Nominations in any one year shall be double the number of positions available for each district that year, with the nominations listed separately by districts.

(c) The elected members of the Nominating Committee each year shall include one from each district represented on the Board of Direction and one at-large member. Nominations in any year shall be double the number of positions available for each district, with the nominations listed separately by districts.

(d) The Chairman of the Nominating Committee shall send the names of the nominees to the President and Executive Secretary within 15 days after the meeting of the Nominating Committee, and the Executive Secretary shall report the names of these nominees to the members of the Association not less than 60 days prior to the annual convention.

(e) At any time prior to 30 days before the annual convention, any ten or more Members may send to the Executive Secretary additional nominations for any elective office for the ensuing year, signed by such Members.

(f) If any person nominated shall be found by the Board of Direction to be ineligible for the office for which nominated, or should a nominee decline such nomination, his name shall be withdrawn. The Board of Direction may fill any vacancies that may occur in the list of nominees up to the time the ballots are sent out.

3. Ballots Issued

Not less than thirty days prior to each annual convention, the Executive Secretary shall issue a ballot to each voting Member of record who has paid his dues to or beyond December 31 of the previous year, listing by districts the several candidates to be voted upon. When there is more than one candidate for any office, the names shall be arranged on the ballot in the order within each district that shall be determined by lot by the Nominating Committee. The ballot shall be accompanied by a statement giving for each candidate his record of membership and activities in the Association.

4. Substitution of Names

Members may remove names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

5. Ballots

(a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed to or deposited with the Executive Secretary at any time previous to the closure of the polls.

(b) A voter may have the privilege of withdrawing his ballot, for the purposes of casting another, or otherwise, at any time up to ten working days prior to the closure of the polls. After that date, no ballot shall be subject to withdrawal or revision.

(c) Ballots received in unendorsed envelopes, or from persons not qualified to vote, shall not be counted.

(d) The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

6. Closure of Polls

The polls shall be closed at 12 o'clock noon on the first day of normal 2½-day annual conventions, and at 4 pm on the day prior to the first day of annual conventions which are less than 2½ days in length. In both instances, the ballots shall be counted by tellers appointed by the presiding officer.

7. Election

(a) The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

(b) In case of a tie between two or more candidates for the same office, the Members present at the annual convention shall elect the officer by ballot from the candidates so tied.

(c) The presiding officer shall announce at the convention the names of the officers elected in accordance with this Article.

Article VII

Management

1. Board of Direction

(a) The Board of Direction shall be the governing body of the Association and shall manage the affairs of the Association in accordance with the Constitution of the Association, and shall have full power to control and regulate all matters not otherwise provided for in the Constitution. It shall be composed of seventeen Members of the Association, and shall include the President and two Vice Presidents of the Association, the two living junior Past Presidents, and twelve elected Directors. The nomination and election of the Officers and Directors shall be in accordance with the procedures set forth in Article VI herein.

(b) Furthermore, the membership shall, insofar as possible, include proportional representation from the territorial divisions contained in the "List of Principal Railroads Showing Allocation to Geographical Groups" (published in the current issue of The Official Railway Equipment Register).

Accordingly, the twelve Directors shall be elected in accordance with Article VI, Section 2, to fit, insofar as possible, the following general plan for territorial representation:

Four from the Eastern District, including the Allegheny and Pocahontas Districts; two from the Southern District; five from the Western District, including the Northwestern, Central Western and Southwestern Districts; and one from Canada.

(c) The President and two Vice Presidents of the Association and the two Past Presidents on the Board of Direction shall be at-large members of the Board.

(d) Vacancies occurring in Director positions prior to normal expiration of term of office shall be filled by the Board, insofar as possible, from the district represented by the previous incumbent.

(e) The Board of Direction shall meet within thirty days after each annual convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board of Direction.

(f) Seven members of the Board of Direction shall constitute a quorum.

2. Executive Committee

(a) An Executive Committee of the Board of Direction shall be constituted annually and shall consist of the President and two Vice Presidents of the Association and the two Past Presidents on the Board of Direction. The Executive Committee shall be subject to confirmation of the Board of Direction each year at the first meeting of the Board following the Convention. The President of the Association shall be the chairman of the Executive Committee.

(b) The Executive Committee shall possess and may exercise during intervals between meetings of the Board, all of the powers of the Board on matters which in the judgment of a majority of the Executive Committee cannot properly be delayed until the next meeting of the Board. Actions of the Executive Committee shall be authorized by a concurring majority of its full membership and shall be reported to the Board of Direction at its next meeting.

(c) The Executive Committee may be dissolved at any time by action of a majority of the full membership of the Board of Direction. Following such dissolution, the Executive Committee may be re-created with personnel different than prescribed in Paragraph (a) herein at any time prior to the Annual Convention by action of a majority of the full membership of the Board. However, if the Executive Committee is not re-created prior to the next Annual Convention it automatically shall come under the provision of Paragraph (a) herein unless the Board of Direction decrees otherwise.

3. President

The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association, the Board of Direction and the Executive Committee of the Board of Direction, and, by virtue of his office, shall be a member of all committees, except the Nominating Committee.

4. Vice Presidents

The Vice Presidents, in order of seniority, shall preside at meetings in the absence of the President.

5. Treasurer

The Treasurer shall pay all bills of the Association when properly certified by the Executive Secretary and approved by the Finance Committee. He shall make an annual report as to the financial condition of the Association and such other reports as may be called for by the Board of Direction.

6. Executive Secretary

The Executive Secretary, under the direction of the President and Board of Direction, shall be the Executive Officer of the Association and shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and record the proceedings thereof. The Executive Secretary shall see that all money due the Association is collected, is credited to the proper accounts, and is deposited in the designated depository of the Association, with receipt to the Treasurer therefor. He shall personally certify to the accuracy of all bills and vouchers on which money is to be paid. He shall invest all funds of the Association not needed for current disbursements, as shall be recommended by the Finance Committee and approved by the Board of Direction, with notification to the Treasurer of such investments. The Executive Secretary shall conduct the correspondence of the Association, make an annual report to the Association, and perform such other duties as the Board of Direction may prescribe.

7. Auditing of Accounts

The financial accounts of the Association shall be audited annually by an accountant or accountants approved by and under the direction of the Finance Committee.

8. Administrative Committees

At the first meeting of the Board of Direction after the annual convention, the following Administrative Committees, each consisting of not less than three members, shall be appointed by the President. The personnel of these committees shall be subject to approval by the Board of Direction.

Assignments
Finance
Manual
Membership
Personnel
Publications
Research

Other special Administrative Committees may be appointed by the President at any time, and reappointed annually, if necessary, their personnel being subject to approval by the Board of Direction.

Membership on Administrative Committees shall be restricted to members of the Board of Direction, except that one or two members of the Administrative Committee on Research may be past members of the Board of Direction.

9. Study and Research Committees

The Board of Direction may establish continuing or special Study and Research Committees to investigate, consider, and report upon subjects appropriate to the object of the Association, as set forth in Art. I.

10. Duties of Administrative Committees

(a) Assignments

The Assignments Committee shall review and pass upon the recommendations of Association Study and Research Committees for subjects to be investigated, considered and reported on by these committees during the ensuing Association year, and shall report thereon to the Board of Direction for its approval. The Assignments Committee shall have authority to assign additional subjects or change the scope of any existing subjects at any time during the year, reporting its action thereon to the Board at its next regular meeting.

(b) Finance

The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of funds and other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by authority of the Board of Direction.

(c) Manual

The Manual Committee, with the assistance of the Publications Committee, shall have general supervision over the Manual.

(d) Membership

The Membership Committee shall investigate applicants for membership and shall make recommendations to the Board of Direction with reference thereto.

(e) Personnel

The Personnel Committee shall review and pass upon applications of members for appointment to Study and Research Committees, and shall also appoint the chairman and vice chairman of such committees and make a report thereon to the Board of Direction for its approval. Should an unexpected vacancy in chairmanship or vice chairmanship of any such committee occur, the Personnel Committee shall have authority to fill such vacancy immediately, reporting its action thereon to the Board at its next regular meeting.

(f) Publications

The Publications Committee shall have general supervision over the publications of the Association. The Publications Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money except by authority of the Board of Direction.

(g) Research

The Research Committee shall encourage and coordinate the research activities of the Association, in the course of accomplishment of which it shall review and pass upon the recommendations of Study and Research Committees for research projects and shall report thereon to the Board of Direction, recommending for approval specific projects initiated by these committees or by the Research Committee and recommending allotments of funds for these projects in the research budget of the Association of American Railroads or from other sources compatible therewith; shall collaborate closely with the research staff of the Association of American Railroads; and when called upon by the Vice President—Research or the Vice President—Operations and Maintenance of that association, members of the Research Committee shall engage in the activities of advisory committees or groups of that organization and shall report from time to time to the Board of Direction on those activities.

11. Special Committees

The Board of Direction may appoint special committees to examine into and report upon any subject connected with the objects of this Association.

12. Discussion by Non-Members

The Board of Direction may invite discussions of reports from persons not members of the Association.

13. Sanction of Act of Board of Direction

An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next annual convention of the Association shall be deemed to be the act of the Association.

Article VIII
Meetings

1. Annual Convention

(a) The Annual Convention of the Association shall be held in the City of Chicago, Ill., or in such other city as may be determined by the affirmative vote of two-thirds of the entire membership of the Board of Direction. The convention in any year shall be held on dates determined by the affirmative vote of two-thirds of the entire membership of the Board of Direction.

(b) The Executive Secretary shall notify all members of the Association of the time and place of the annual convention at least 30 days in advance thereof.

(c) The order of business at the annual convention of the Association shall be:

Reading of the minutes of the last meeting
Address of the President
Reports of the Executive Secretary and the Treasurer
Reports of committees
Unfinished business
New business
Installation of officers
Adjournment

(d) This order of business may be changed by a majority vote of Members present.

(e) The proceedings shall be governed by "Robert's Rules of Order" except as otherwise herein provided.

(f) Discussions shall be limited to Members and to those others invited by the presiding officer to speak.

2. Special Meetings

Special meetings of the Associations may be called by the Board of Directions on its own initiative, and may be so called by the Board of Direction upon written request of 100 Members. The request shall state the purpose of such meeting.

The call for such special meeting shall be issued not less than ten days in advance of the proposed date of such meeting and shall state the purpose and place of the meeting. No other business shall be taken up at such meeting.

3. Quorum

Twenty-five Members shall constitute a quorum at all meetings of the Association.

Article IX
Amendment

1. Amendment

Proposed amendment of this Constitution shall be made in writing, shall be signed by not less than ten Members, and shall be acted upon in the following manner:

The amendment shall be presented to the Executive Secretary, who shall send a copy to each member of the Board of Direction as soon as received. If a majority of the entire Board of Direction so votes, the matter shall be submitted to the Association by letter ballot.

Sixty days after the date of issue of the letter ballot, the Board of Direction shall canvass the ballots which have been received, and if two-thirds of such ballots are in the affirmative the amendment shall be declared adopted and shall become effective immediately. The result of the letter ballot shall be announced to members of the Association.

CROSS

District and Road
EASTERN DISTRICT:
Akron, Canton & Youngsto
Ann Arbor
Baltimore & Ohio
Bangor & Aroostook
Bessemer & Lake Erie
Boston & Maine
Canadian Pacific(Lines i
Central RR of New Jersey
Central Vermont
Chesapeake & Ohio
Chicago & Eastern Illinc
Chicago & Illinois Midla
Delaware & Hudson
Detroit & Toledo Shore I
Detroit, Toledo & Ironto
Elgin, Joliet & Eastern
Erie Lackawanna
Grand Trunk Western
Illinois Terminal
Lehigh Valley
Long Island
Maine Central
Missouri-Illinois
Monon
New York Central
New York, New Haven & Ha
Norfolk & Western
Pennsylvania
Penna-Reading Seashore I
Pittsburgh & Lake Erie
Reading
Richmond Fred'burg & Po
Western Maryland
Total Eastern District
SOUTHERN DISTRICT:
Alabama Great Southern
Central of Georgia
Cincinnati,New Orleans & Texas Pacific
Clinchfield
Florida East Coast
Georgia
Georgia Southern & Flor
Gulf, Mobile & Ohio
Illinois Central
Louisville & Nashville
New Orleans & Northeast
Norfolk Southern
Piedmont & Northern
Seaboard Coast Line d
Southern
Total Southern Distri

Table [illegible]

CROSS TIE [illegible] (EXCLUDING SWITCH [illegible] BRIDGE) FOR CLASS [illegible] THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year [illegible] 1967

District and Road	Wooden cross ties laid in replacement			Track miles [illegible] reporting railroad			Equated gross ton-miles (thousands) a		New cross tie replacement averages			
	New ties		Second hand ties	Miles occupied by cross ties	Total cross ties	Cross ties per mile	Total	Per mile of track	Percent renewal to all ties	Number laid per mile	Renewal cost per mile	Renewal cost per 1,000 GTM
	Number	Average cost b										
	1	2	3	4	5	6	7	8	9	10	11	12
EASTERN DISTRICT:												
Akron, Canton & Youngstown	19 923	$4.[illegible]	1 342	219.67	648 088	2 950	932 911	4 247	4.62	136	$657	15.48¢
Ann Arbor	2 797	4.50	682	393.83	1 198 031	3 042	1 174 418	2 982	.23	7	32	1.07
Baltimore & Ohio	499 967	4.62	-	9 189.47	26 649 463	2 900	76 692 644	8 346	1.88	54	251	3.01
Bangor & Aroostook	21 839	3.70	4 500	765.98	2 201 387	2 874	1 816 778	2 372	.99	29	106	4.45
Bessemer & Lake Erie	c 25 441	c 6.49	1 768	383.06	1 149 180	3 000	4 651 959	12 144	2.22	67	465	3.83
Boston & Maine	7 056	4.39	49 881	2 167.52	6 394 184	2 950	7 627 213	3 519	.11	3	14	.41
Canadian Pacific (Lines in Me.)	25 704	4.45	105	208.36	611 573	2 935	1 418 067	6 806	4.20	123	548	8.06
Central RR of New Jersey	2 788	2.78	-	1 155.18	2 952 394	2 556	4 823 107	4 175	.09	2	7	.16
Central Vermont	6 464	4.28	4 206	414.20	1 193 725	2 882	1 307 298	3 156	.54	16	67	2.12
Chesapeake & Ohio	313 445	4.63	-	8 169.53	24 508 590	3 000	79 849 559	9 774	1.28	38	178	1.82
Chicago & Eastern Illinois	281 949	5.13	-	1 208.43	3 677 615	3 043	7 813 688	6 466	7.67	233	1 198	18.53
Chicago & Illinois Midland	1 887	6.05	548	162.80	488 388	3 000	812 725	4 992	.39	12	70	1.41
Delaware & Hudson	34 107	4.40	-	1 082.42	3 355 967	3 100	8 899 999	8 222	1.02	32	139	1.69
Detroit & Toledo Shore Line	1 164	3.26	Cr 49	147.74	427 916	2 896	574 094	3 886	.27	8	26	.66
Detroit, Toledo & Ironton	11 471	4.89	5 145	638.33	1 839 830	2 880	2 737 502	4 285	.62	18	88	2.05
Elgin, Joliet & Eastern	49 628	4.69	613	824.83	2 522 005	3 058	2 020 597	2 450	1.97	60	282	11.51
Erie Lackawanna	312 447	5.47	12 720	5 516.53	16 327 129	2 960	43 202 876	7 832	1.91	57	310	3.95
Grand Trunk Western	46 169	5.02	306	1 831.69	5 773 341	3 152	9 814 298	5 358	.80	25	127	2.36
Illinois Terminal	16 336	4.07	2 995	352.59	1 090 984	3 094	1 048 642	2 974	1.50	46	189	6.34
Lehigh Valley	2 626	3.46	-	1 706.71	5 389 086	3 158	7 615 639	4 462	.05	2	5	.12
Long Island	33 160	4.52	-	638.91	1 807 179	2 829	3 623 491	5 671	1.83	52	235	4.14
Maine Central	68 363	4.51	1 721	1 065.79	3 188 880	2 992	2 783 748	2 612	2.14	64	289	11.07
Missouri-Illinois	4 280	4.08	-	197.27	609 946	3 092	829 106	4 203	.70	22	89	2.11
Monon	35 659	5.74	-	709.64	2 206 771	3 110	3 310 632	4 665	1.62	50	288	6.18
New York Central	602 014	5.07	130 544	16 168.48	50 799 190	3 142	119 046 574	7 363	1.19	37	189	2.56
New York, New Haven & Hartford	50 543	5.04	-	3 017.37	9 559 028	3 168	13 419 324	4 447	.53	17	84	1.90
Norfolk & Western	378 876	5.14	2 234	12 166.44	37 847 518	3 111	121 589 840	9 994	1.00	31	160	1.60
Pennsylvania	786 904	4.53	459	18 351.15	52 612 374	2 867	156 597 081	8 533	1.50	43	196	2.30
Penna-Reading Seashore Lines	-	-	13 684	446.31	1 208 946	2 709	456 863	1 024	-	-	-	-
Pittsburgh & Lake Erie	21 191	6.53	3 069	599.23	1 833 065	3 059	2 720 976	4 541	1.16	35	231	5.09
Reading	122 695	5.46	442	2 352.04	6 478 112	2 754	12 148 270	5 165	1.89	52	285	5.52
Richmond Fred'burg & Potomac	34 221	4.71	661	432.93	1 395 375	3 223	4 649 182	10 739	2.45	79	373	3.47
Western Maryland	51 016	5.83	-	1 132.92	3 287 338	2 902	7 972 702	7 037	1.55	45	262	3.73
Total Eastern District	c 3 882 200	c 4.91	237 576	93 817.85	281 232 598	2 998	713 981 803	7 610	1.38	41	203	2.67
SOUTHERN DISTRICT:												
Alabama Great Southern	29 544	5.48	-	550.23	1 695 907	3 082	5 220 051	9 487	1.74	54	294	3.10
Central of Georgia	266 717	5.48	-	2 142.99	6 751 645	3 151	8 601 099	4 014	3.95	124	681	16.98
Cincinnati, New Orleans & Texas Pacific	51 767	5.52	-	707.57	2 195 451	3 103	11 234 776	15 878	2.36	73	404	2.54
Clinchfield	33 178	6.01	308	435.57	1 411 247	3 240	8 334 800	19 135	2.35	76	458	2.39
Florida East Coast	c 70 813	c 6.74	7 501	1 168.04	3 521 976	3 015	4 050 662	3 468	2.01	61	409	11.79
Georgia	30 410	4.62	-	432.06	1 316 147	3 046	2 065 813	4 781	2.31	70	325	6.80
Georgia Southern & Florida	51 092	5.53	-	476.14	1 496 954	3 144	2 898 723	6 088	3.41	107	593	9.74
Gulf, Mobile & Ohio	187 404	4.11	13 866	3 373.97	10 688 737	3 168	20 497 629	6 075	1.75	56	228	3.75
Illinois Central	581 431	4.53	-	9 401.43	29 849 822	3 175	60 410 682	6 426	1.95	62	281	4.37
Louisville & Nashville	546 917	4.16	28 562	7 981.42	22 859 965	2 864	68 208 625	8 546	2.39	69	285	3.33
New Orleans & Northeastern	20 283	5.58	-	298.27	923 716	3 097	3 193 213	10 706	2.20	68	379	3.54
Norfolk Southern	52 856	3.50	-	751.95	2 167 053	2 882	1 863 806	2 479	2.44	70	246	9.93
Piedmont & Northern	12 173	6.59	191	213.00	655 065	3 075	448 586	2 106	1.86	57	377	17.89
Seaboard Coast Line d	c 1 293 744	c 4.76	-	12 913.12	40 206 298	3 114	98 010 715	7 590	3.22	100	477	6.29
Southern	454 542	5.50	-	8 268.02	25 824 211	3 123	59 179 648	7 158	1.76	55	303	4.23
Total Southern District	c 3 682 871	c 4.81	50 428	49 113.78	151 564 194	3 086	354 218 828	7 212	2.43	75	361	5.01

CROS

District and Roa
WESTERN DISTRICT:
Atchison, Topeka & Santa
Chicago & North Western
Chicago, Burlington & Qu
Chicago Great Western
Chicago, Milwaukee, St. Pac.
Chicago, Rock Island &
Colorado & Southern
Denver & Rio Grande Wes
Duluth, Missabe & Iron
Duluth, Winnipeg & Paci
Fort Worth & Denver
Great Northern
Kansas City Southern
Lake Superior & Ishpemi
Louisiana & Arkansas
Missouri-Kansas-Texas
Missouri Pacific
Northern Pacific
Northwestern Pacific
St. Louis-San Francisco
St. Louis Southwestern
Soo Line
Southern Pacific Co.
Spokane, Portland & Sea
Texas & Pacific
Toledo, Peoria & Wester
Union Pacific
Western Pacific
Total Western Distric
Total United States
CANADIAN ROADS: *
Canadian National
Canadian Pacific
Ontario Northland

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b - "Average
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c - Comprise

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Association
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CROSS TIE STATISTICS (EXCLUDING SWITCH AND BRIDGE TIES) CLASS I RAILROADS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1967

District and Road	Wooden cross ties laid in replacement: New ties: Number	Wooden cross ties laid in replacement: New ties: Average cost b	Wooden cross ties laid in replacement: Second hand ties	Track maintained by reporting railroad: Miles occupied by cross ties	Track maintained by reporting railroad: Total cross ties	Track maintained by reporting railroad: Cross ties per mile	Equated gross ton-miles (thousands) a: Total	Equated gross ton-miles (thousands) a: Per mile of track	New cross tie replacement averages: Percent renewal to all ties	New cross tie replacement averages: Number laid per mile	New cross tie replacement averages: Renewal cost per mile	New cross tie replacement averages: Renewal cost per 1,000 GTM
	1	2	3	4	5	6	7	8	9	10	11	12
WESTERN DISTRICT												
Atchison, Topeka & Santa Fe	1 143 812	$4.04	-	19 454.28	62 133 481	3 193	180 266 730	9 264	1.84	59	$237	2.56¢
Chicago & North Western	539 611	5.14	83 272	13 072.23	38 917 859	2 977	45 912 773	3 512	1.39	41	212	6.04
Chicago, Burlington & Quincy	286 729	4.22	25 923	11 136.24	34 388 709	3 088	62 979 540	5 655	.83	26	109	1.92
Chicago Great Western	73 835	4.03	3 140	1 732.26	5 207 065	3 006	6 384 773	3 686	1.42	43	172	4.66
Chicago, Milwaukee, St. Paul & Pac.	239 155	4.34	23 790	12 988.89	39 390 339	3 033	52 091 636	4 010	.61	18	80	1.99
Chicago, Rock Island & Pacific	339 334	3.73	55 427	8 983.64	26 771 200	2 980	53 689 987	5 976	1.27	38	141	2.36
Colorado & Southern	43 215	4.21	1 307	760.82	2 328 195	3 060	3 266 229	4 293	1.86	57	239	5.57
Denver & Rio Grande Western	115 577	4.27	6 948	3 067.77	9 470 253	3 087	21 523 500	7 016	1.22	38	161	2.29
Duluth, Missabe & Iron Range	19 161	6.25	6 969	852.55	2 539 732	2 979	3 588 345	4 209	.75	22	140	3.34
Duluth, Winnipeg & Pacific	8 148	4.36	-	205.18	593 045	2 890	1 569 086	7 647	1.38	40	174	2.27
Fort Worth & Denver	49 638	4.08	1 509	1 524.10	4 574 254	3 001	3 902 205	2 560	1.06	32	130	5.08
Great Northern	348 131	4.64	54 749	9 973.67	30 970 742	3 105	54 650 645	5 479	1.12	35	162	2.96
Kansas City Southern	c 53 984	c 4.19	-	1 378.91	4 357 947	3 160	10 271 091	7 449	1.24	39	164	2.20
Lake Superior & Ishpeming	989	4.58	4 599	203.66	610 980	3 000	164 558	808	.16	5	22	2.75
Louisiana & Arkansas	44 931	3.77	-	887.59	2 892 867	3 259	5 383 446	6 065	1.55	51	191	3.14
Missouri-Kansas-Texas	320 836	3.93	-	3 116.57	9 986 997	3 204	13 373 436	4 291	3.21	103	405	9.43
Missouri Pacific	558 415	4.12	-	10 964.84	33 854 941	3 088	66 830 766	6 095	1.65	51	210	3.44
Northern Pacific	305 457	3.99	2 994	9 011.76	26 112 250	2 898	45 406 032	5 039	1.17	34	135	2.68
Northwestern Pacific	22 560	4.72	-	403.97	1 163 434	2 880	1 403 048	3 473	1.94	56	264	7.60
St. Louis-San Francisco	379 589	3.60	-	5 763.67	18 091 921	3 139	34 460 558	5 979	2.10	66	237	3.96
St. Louis Southwestern	133 973	4.61	2 078	1 742.01	5 335 934	3 063	23 697 916	13 604	2.51	77	354	2.60
Soo Line	240 338	3.95	579	5 259.70	15 822 642	3 008	15 840 010	3 012	1.52	46	180	5.99
Southern Pacific Co.	678 299	4.61	17 994	16 470.50	48 587 951	2 950	168 548 640	10 233	1.40	41	190	1.86
Spokane, Portland & Seattle	51 209	4.72	-	1 130.29	3 495 833	3 093	7 862 163	6 956	1.46	45	214	3.07
Texas & Pacific	197 175	4.10	-	2 408.44	7 343 163	3 049	16 217 215	6 733	2.69	82	336	4.99
Toledo, Peoria & Western	14 641	3.39	-	295.02	934 623	3 168	1 130 976	3 834	1.57	50	168	4.39
Union Pacific	568 147	4.52	55 251	13 215.54	37 366 923	2 827	147 883 474	11 190	1.52	43	195	1.74
Western Pacific	c 82 459	c 6.49	-	1 548.19	4 620 646	2 985	14 737 763	9 519	1.78	53	346	3.63
Total Western District	c 6 855 398	c 4.29	351 629	157 557.29	477 863 928	3 033	1 063 036 541	6 747	1.44	44	187	2.77
Total United States	c 14 423 459	c 4.59	639 633	300 488.92	910 660 720	3 031	2 131 237 172	7 093	1.58	48	220	3.11
CANADIAN ROADS: *												
Canadian National	99 735	3.38	-	29 221.	85 930 9[illegible]1	2 941	e	e	1.2	34	115	e
Canadian Pacific	1 216 106	4.04	-	20 702.01	60 689 034	2 951	46 466 331	4 660	2.00	59	237	5.09
Ontario Northland	72 231	5.21	-	695.4	2 043 910	2 939	2 824 192	3 811	3.58	105	549	14.39

* - Not reported.

a - Gross ton-miles of cars and contents, plus two times gross ton-miles of locomotives and tenders in freight service, plus three times gross ton-miles of locomotives and tenders in passenger service.

b - "Average cost" represents storekeepers' average cost of all kinds, sizes and grades of ties charged out and used rather than the average price of ties purchased during the year.

c - Comprised of both other than wooden and wooden ties as follows

Item	Other than wooden ties: Type	Other than wooden ties: Number	Other than wooden ties: Average cost	Wooden ties: Number	Wooden ties: Average cost
Road:					
Bessemer & Lake Erie	Steel	24	$47.21	25 467	$6.95
Florida East Coast	Concrete	11 008	11.33	59 805	5.90
Seaboard Coast Line d	Concrete	1 330	11.16	1 292 414	4.76
Kansas City Southern	Concrete	3 411	11.20	50 573	3.72
Western Pacific	Not reported	300	14.42	82 159	6.46
District:					
Eastern District	xxx	24	47.21	3 882 176	4.91
Southern District	xxx	12 338	11.32	3 670 533	4.79
Western District	xxx	3 711	11.46	6 854 677	4.28
United States	xxx	16 073	11.40	14 407 386	4.58

d - Atlantic Coast Line and Seaboard Air Line railroads merged to form Seaboard Coast Line Railroad effective July 1, 1967. Statistics shown for Seaboard Coast Line include the separate operations of the two railroads.

Association of American Railroads, Economics and Finance Department, Washington, D.C., from Annual Reports of Class I Railroads to the Interstate Commerce Commission.

NUMBER AND

Class I roa

District and Road
EASTERN DISTRICT:
Akron, Canton & Youngsto
Ann Arbor
Baltimore & Ohio
Bangor & Aroostook
Bessemer & Lake Erie
Boston & Maine
Canadian Pacific (Lines
Central RR of New Jersey
Central Vermont
Chesapeake & Ohio
Chicago & Eastern Illino:
Chicago & Illinois Midlai
Delaware & Hudson
Detroit & Toledo Shore L:
Detroit, Toledo & Irontoi
Elgin, Joliet & Eastern
Erie Lackawanna
Grand Trunk Western
Illinois Terminal
Lehigh Valley
Long Island
Maine Central
Missouri-Illinois
Monon
New York Central
New York, New Haven & Har
Norfolk & Western
Pennsylvania
Penna-Reading Seashore Li
Pittsburgh & Lake Erie
Reading
Richmond Fred'burg & Potc
Western Maryland
Total Eastern District
SOUTHERN DISTRICT:
Alabama Great Southern
Central of Georgia
Cincinnati, New Orleans &
Clinchfield
Florida East Coast
Georgia
Georgia Southern & Florid
Gulf, Mobile & Ohio
Illinois Central
Louisville & Nashville
New Orleans & Northeaster
Norfolk Southern
Piedmont & Northern
Seaboard Coast Line c
Southern
Total Southern District

Table B

NUMBER AND AGGREGATE COST OF NEW CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of five years 1963 to 1967, inclusive

Note All figures are exclusive of bridge and switch ties

District and Road	Number of new cross tie renewals per mile of maintained track						Aggregate cost of new cross tie renewals per mile of maintained track						Percent new cross tie renewals to all ties in tracks					
	1963	1964	1965	1966	1967	5 year average	1963	1964	1965	1966	1967	5 year average	1963	1964	1965	1966	1967	5 year average
EASTERN DISTRICT.																		
Akron, Canton & Youngstown	1	1	108	116	136	72	$2	$2	$566	$629	$657	$371	.02	.02	3.67	3.92	4.62	2.45
Ann Arbor	8	35	11	15	7	15	38	164	49	66	32	70	.25	1.15	.35	.48	.23	.49
Baltimore & Ohio	67	49	51	62	54	57	257	196	190	284	251	236	2.31	1.69	1.75	2.14	1.88	1.95
Bangor & Aroostook	94	96	96	93	29	82	374	377	373	351	106	316	3.25	3.35	3.33	3.23	.99	2.83
Bessemer & Lake Erie	35	41	56	67	67	53	162	166	316	440	465	310	1.18	1.35	1.88	2.22	2.22	1.77
Boston & Maine	3	7	4	9	3	5	11	26	14	38	14	21	.11	.23	.12	.31	.11	.18
Canadian Pacific (Lines in Me.)	100	113	53	55	123	89	360	408	178	218	548	342	3.79	3.85	1.92	1.85	4.20	3.12
Central RR of New Jersey	25	7	4	2	2	8	72	16	7	5	7	21	.88	.27	.13	.06	.09	.29
Central Vermont	79	49	36	13	16	39	338	226	162	36	67	166	2.70	1.69	1.22	.44	.54	1.32
Chesapeake & Ohio	31	44	53	38	38	41	123	181	223	168	178	175	1.04	1.48	1.77	1.25	1.28	1.36
Chicago & Eastern Illinois	41	56	48	63	233	88	167	233	198	282	198	416	1.34	1.86	1.59	2.05	7.67	2.90
Chicago & Illinois Midland	30	7	21	17	12	17	159	34	116	90	70	94	.99	.23	.71	.56	.39	.58
Delaware & Hudson	1	9	28	26	32	19	6	37	114	108	139	81	.05	.29	.90	.83	1.02	.62
Detroit & Toledo Shore Line	7	59	93	61	8	46	33	318	487	348	26	242	.23	2.04	3.23	2.10	.27	1.57
Detroit, Toledo & Ironton	38	49	52	40	18	39	148	210	239	174	88	172	1.30	1.71	1.80	1.38	.62	1.36
Elgin, Joliet & Eastern	51	60	71	78	60	64	208	234	273	350	282	269	1.66	1.95	2.30	2.54	1.97	2.08
Erie Lackawanna	-	1	32	47	57	27	2	5	171	241	310	146	.02	.03	1.03	1.58	1.91	.91
Grand Trunk Western	33	37	30	31	25	31	142	167	146	155	127	147	1.03	1.18	.95	.97	.80	.99
Illinois Terminal	2	22	47	37	46	31	10	73	166	138	189	115	.08	.72	1.51	1.19	1.50	1.00
Lehigh Valley	15	5	7	-	2	6	59	16	27	-	5	21	.50	.15	.27	-	.05	.19
Long Island	67	34	57	58	52	54	236	115	248	263	235	219	2.43	1.19	2.07	2.10	1.83	1.92
Maine Central	64	61	61	58	64	62	249	236	242	248	289	253	2.13	2.03	2.03	1.94	2.14	2.05
Missouri-Illinois	1	4	a	a	22	b 9	2	14	a	a	89	b 35	.02	.13	a	a	.70	b .28
Monon	46	47	49	49	50	48	174	174	214	239	288	218	1.49	1.52	1.58	1.56	1.62	1.55
New York Central	9	16	30	36	37	26	41	78	149	186	189	129	.29	.52	.98	1.19	1.19	.83
New York, New Haven & Hartford	27	27	28	32	17	26	105	101	112	161	84	113	.87	.85	.89	1.02	.53	.83
Norfolk & Western	29	39	39	45	31	37	135	175	192	211	160	175	.93	.80	1.27	1.43	1.00	1.09
Pennsylvania	31	39	43	36	43	38	127	146	180	165	196	163	1.08	1.37	1.49	1.25	1.50	1.34
Penna-Reading Seashore Lines	64	29	37	29	-	32	244	115	171	151	-	136	2.37	1.08	1.41	1.07	-	1.19
Pittsburgh & Lake Erie	4	10	30	30	35	22	16	43	148	160	231	120	.12	.32	1.00	.98	1.16	.72
Reading	49	57	72	58	52	58	172	237	337	297	285	266	1.72	2.00	2.60	2.09	1.89	2.06
Richmond Fred'burg & Potomac	29	45	49	69	79	54	132	210	244	343	373	260	.90	1.38	1.51	2.13	2.45	1.67
Western Maryland	51	52	52	59	45	52	228	235	246	293	262	253	1.77	1.78	1.80	2.03	1.55	1.79
Total Eastern District	29	33	40	41	41	37	119	136	178	196	203	166	.98	1.10	1.35	1.38	1.38	1.24
SOUTHERN DISTRICT:																		
Alabama Great Southern	27	66	62	55	54	53	129	321	327	257	294	266	.88	2.15	2.02	1.78	1.74	1.71
Central of Georgia	96	97	121	110	124	110	325	357	532	568	681	493	3.31	2.40	3.83	3.49	3.95	3.40
Cincinnati, New Orleans & Tex. Pac.	33	65	97	59	73	65	160	324	510	297	404	339	1.11	2.10	3.13	1.90	2.36	2.12
Clinchfield	29	34	45	36	76	44	121	142	190	184	458	219	.88	1.05	1.40	1.10	2.35	1.36
Florida East Coast	8	36	39	50	61	39	38	164	183	405	409	240	.28	1.20	1.29	1.68	2.01	1.29
Georgia	83	85	64	85	70	77	325	348	268	332	325	320	2.75	2.80	2.11	2.80	2.31	2.55
Georgia Southern & Florida	38	6	62	64	107	55	181	27	320	339	593	292	1.21	.18	1.96	2.02	3.41	1.76
Gulf, Mobile & Ohio	37	44	51	51	56	48	131	157	186	195	228	179	1.17	1.38	1.62	1.61	1.75	1.51
Illinois Central	48	52	50	50	62	52	200	222	213	221	281	227	1.59	1.69	1.65	1.62	1.95	1.70
Louisville & Nashville	66	60	71	66	69	66	249	237	282	285	285	268	2.35	2.11	2.51	2.33	2.39	2.34
New Orleans & Northeastern	112	18	85	46	68	66	541	91	440	244	379	339	3.79	.58	2.76	1.48	2.20	2.16
Norfolk Southern	61	74	71	70	70	69	183	243	244	234	246	230	2.10	2.55	2.42	2.42	2.44	2.39
Piedmont & Northern	106	74	47	41	57	65	531	365	232	224	377	346	3.43	2.39	1.51	1.34	1.86	2.11
Seaboard Coast Line c	71	67	76	87	100	80	274	263	316	383	477	343	2.30	2.18	2.46	2.83	3.22	2.60
Southern	28	81	65	43	55	54	136	401	339	228	303	281	.88	2.59	2.07	1.38	1.76	1.74
Total Southern District	54	62	67	65	75	65	214	261	293	296	361	285	1.79	2.02	2.20	2.12	2.43	2.11

NUMBER AND

Class I road

District and Road
WESTERN DISTRICT:
Atchison, Topeka & Santa
Chicago & North Western
Chicago, Burlington & Qu
Chicago Great Western
Chicago, Milwaukee, St.
Chicago, Rock Island & P
Colorado & Southern
Denver & Rio Grande West
Duluth, Missabe & Iron R
Duluth, Winnipeg & Pacif
Fort Worth & Denver
Great Northern
Kansas City Southern
Lake Superior & Ishpemin
Louisiana & Arkansas
Missouri-Kansas-Texas
Missouri Pacific
Northern Pacific
Northwestern Pacific
St. Louis-San Francisco
St. Louis Southwestern
Soo Line
Southern Pacific Co.
Spokane, Portland & Seatt
Texas & Pacific
Toledo, Peoria & Western
Union Pacific
Western Pacific
Total Western District
Total United States
CANADIAN ROADS:
Canadian National
Canadian Pacific
Ontario Northland

Table B

NUMBER AND AGGREGATE COST OF NEW CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class 1 roads in the United States and large Canadian roads, by years, and for the average of five years 1963 to 1967, inclusive

Note All figures are exclusive of bridge and switch ties

District and Road	Number of new cross tie renewals per mile of maintained track						Aggregate cost of new cross tie renewals per mile of maintained track						Percent new cross tie renewals to all ties in tracks					
	1963	1964	1965	1966	1967	5 year average	1963	1964	1965	1966	1967	5 year average	1963	1964	1965	1966	1967	5 year average
WESTERN DISTRICT:																		
Atchison, Topeka & Santa Fe System	28	42	52	55	59	47	$95	$148	$167	$188	$237	$167	.87	1.31	1.63	1.72	1.84	1.47
Chicago & North Western	27	29	39	37	41	35	132	147	187	178	212	171	.91	.98	1.32	1.24	1.39	1.17
Chicago, Burlington & Quincy	25	33	19	28	26	26	92	128	74	109	109	102	.80	1.06	.61	.90	.83	.84
Chicago Great Western	75	42	34	54	43	50	268	144	125	207	172	183	2.51	1.38	1.14	1.81	1.42	1.65
Chicago, Milwaukee, St. Paul & Pac.	26	17	14	41	18	23	110	72	61	170	80	99	.86	.57	.48	1.34	.61	.77
Chicago, Rock Island & Pacific	49	46	43	41	38	43	160	146	137	133	141	143	1.65	1.53	1.43	1.39	1.27	1.45
Colorado & Southern	52	59	38	48	57	51	206	225	148	183	239	200	1.76	1.99	1.20	1.50	1.86	1.66
Denver & Rio Grande Western	28	46	29	41	38	36	117	184	119	164	161	149	.92	1.50	.94	1.32	1.22	1.18
Duluth, Missabe & Iron Range	33	40	47	44	22	37	149	87	181	231	140	158	1.11	1.34	1.57	1.47	.75	1.25
Duluth, Winnipeg & Pacific	39	46	32	42	40	40	99	139	114	158	174	137	1.37	1.62	1.11	1.46	1.38	1.39
Fort Worth & Denver	29	27	27	38	32	31	99	89	92	143	130	111	.95	.91	.91	1.28	1.06	1.02
Great Northern	54	56	32	35	35	42	266	262	150	160	162	200	1.74	1.81	1.03	1.12	1.12	1.36
Kansas City Southern	63	60	41	58	39	52	197	187	131	193	164	174	2.00	1.91	1.29	1.83	1.24	1.65
Lake Superior & Ishpeming	71	25	38	2	5	28	212	78	78	10	22	80	2.38	.85	1.27	.07	.16	.95
Louisiana & Arkansas	104	117	84	119	51	95	325	370	271	400	191	311	3.19	3.58	2.57	3.67	1.55	2.91
Missouri-Kansas-Texas	58	141	123	142	103	113	201	494	431	564	405	419	1.83	4.42	3.86	4.46	3.21	3.56
Missouri Pacific	58	60	65	73	51	61	189	206	232	284	210	224	1.89	1.93	2.11	2.37	1.65	1.99
Northern Pacific	53	52	44	51	34	47	205	196	177	205	135	184	1.82	1.81	1.53	1.77	1.17	1.62
Northwestern Pacific	28	4	67	52	56	41	101	14	307	174	264	172	.98	.13	2.32	1.80	1.94	1.43
St. Louis-San Francisco	59	60	58	75	66	64	183	188	182	250	237	208	1.88	1.92	1.83	2.37	2.10	2.02
St. Louis Southwestern	70	80	60	50	77	67	239	289	251	216	354	270	2.28	2.63	1.96	1.64	2.51	2.20
Soo Line	37	43	49	58	46	47	130	162	186	223	180	176	1.21	1.43	1.61	1.91	1.52	1.54
Southern Pacific Co.	53	46	58	53	41	50	176	142	200	185	190	179	1.76	1.52	2.00	1.80	1.40	1.70
Spokane, Portland & Seattle	52	58	58	69	45	56	226	251	261	332	214	257	1.68	1.87	1.87	2.22	1.46	1.82
Texas & Pacific	30	39	50	41	82	48	102	134	177	148	336	179	1.03	1.33	1.70	1.34	2.69	1.62
Toledo, Peoria & Western	34	46	52	46	50	46	92	154	187	162	168	153	1.07	1.46	1.64	1.44	1.57	1.44
Union Pacific	52	39	48	37	43	44	219	163	203	160	195	188	1.85	1.38	1.67	1.28	1.52	1.54
Western Pacific	52	44	45	48	53	48	284	257	277	328	346	298	1.73	1.46	1.51	1.62	1.78	1.62
Total Western District	43	45	45	50	44	45	162	169	170	194	187	176	1.42	1.49	1.49	1.64	1.44	1.50
Total United States	41	44	47	49	48	46	157	174	193	211	220	191	1.34	1.43	1.57	1.64	1.58	1.51
CANADIAN ROADS:																		
Canadian National	46	43	41	38	34	40	136	144	125	122	115	128	1.60	1.50	1.40	1.29	1.2	1.4
Canadian Pacific	61	54	62	58	59	59	174	168	205	205	237	198	2.08	1.83	2.10	1.96	2.00	1.99
Ontario Northland	93	68	69	84	105	84	375	292	344	437	549	399	2.99	2.28	2.30	2.87	3.58	2.80

a - Not reported. Missouri-Illinois reported as a Class II railroad.
b - Three year average. See note a.
c - Atlantic Coast Line and Seaboard Air Line railroads merged to form Seaboard Coast Line Railroad effective July 1, 1967. Statistics shown for Seaboard Coast Line include the separate operation of the two railroads

Compiled by
Association of American Railroads, Economics and Finance Department, Washington, D.C.
from Annual Reports of Class I Railroads to the Interstate Commerce Commission.

June 1968

Advance Report of Committee 3—Ties and Wood Preservation

Report on Assignment 5

Service Records

J. T. Slocomb (chairman, subcommittee), W. F. Arksey, A. B. Baker, K. C. Edscorn, M. S. Edwards, F. J. Fudge, H. M. Harlow, R. P. Hughes, H. C. Martin, R. B. Radkey, J. L. Williams.

Tie Renewals and Cost per Mile of Maintained Track

The annual statistics compiled by the Economics and Finance Department, Association of American Railroads, providing information on cross tie renewals and average cost data for 1967 are presented herewith in Tables A and B. This year, two additional tables are included. Table C shows the number and average costs of concrete ties laid in replacement and in new lines. Table D shows prices for treated wood cross ties of specific sizes and species paid by 15 selected Class I Railroads, in the three regions of the United States.

The 1967 statistics compared with those of 1966 are as follows:

Year	*Total New Tie Renewals*	*Renewals Per Mile*
1966	14,903,484*	49
1967	14,423,459**	48
Five year average, 1963 to 1967, incl.		46

* Includes 32,409 concrete ties, excludes 442,388 secondhand ties
** Includes 16,073 concrete ties, excludes 639,633 secondhand ties

The average cost for all sizes and species of ties protected with various anti-splitting devices, as charged out by storekeepers, was $4.25 in 1966 and $4.59 in 1967. Concrete (and a few steel) ties are included.

After declining for ten straight years (1951–1961), the average number of new ties laid in replacement, per mile, for the United States, advanced from 35 in 1961 to 49 in 1966. This figure declined in 1967 to 48. Eastern roads held their own—41 in 1966 and 41 in 1967. Southern roads increased—65 in 1966 to 75 in 1967. Western roads declined—50 in 1966 to 44 in 1967.

Total ties replaced in 1967 were 15,063,092. This figure divided into the total number of cross ties supporting maintained track of 76 Class I United States railroads, indicates an average tie life of 60.4 years, still far above the average service life of a wood tie as proven by tie tests.

Several railroads did not charge out secondhand ties in 1967 and their replacement does not show in the table. Hence, this calculated "average tie life" is not quite accurate.

Table C

OTHER THAN WOODEN CROSS TIES LAID IN 1967 AND NUMBER OF OTHER THAN WOODEN CROSS TIES IN MAINTAINED TRACK OCCUPIED BY CROSS TIES AS OF DECEMBER 31, 1967

District and Road	Other than wooden cross ties laid in replacement		Other than wooden cross ties laid in additional tracks, new lines and extensions		Number of other than wooden cross ties in maintained track occupied by cross ties (12/31/67)
	Number	Average cost	Number	Average cost	
EASTERN DISTRICT:					
Baltimore & Ohio	-	-	-	-	a 16 888
Bessemer & Lake Erie	b 24	$47.21	-	-	b c 24
Chesapeake & Ohio	-	-	-	-	1 875
Chicago & Illinois Midland	-	-	-	-	36
Delaware & Hudson	-	-	-	-	62 413
Total Eastern District	b 24	47.21	-	-	81 236
SOUTHERN DISTRICT:					
Florida East Coast	a 11 008	11.33	-	-	a 83 279
Louisville & Nashville	-	-	6 450	$14.62	c 6 450
Norfolk Southern	-	-	a 752	5.15	a 68 579
Seaboard Coast Line d	a 1 330	11.16	a25 480	12.61	175 778
Total Southern District	12 338	11.32	32 682	12.83	334 086
WESTERN DISTRICT:					
Duluth, Missabe & Iron Range	-	-	-	-	530
Kansas City Southern	a 3 411	11.20	2 840	10.66	c 6 251
Northern Pacific	-	-	-	-	82
St. Louis-San Francisco	-	-	a52 735	11.43	a 73 826
Western Pacific	300	14.42	-	-	300
Total Western District	3 711	11.46	55 575	11.39	80 989
Total United States	16 073	11.40	88 257	11.92	496 311

a - Reported specifically as concrete ties.
b - Reported specifically as steel ties.
c - Represents 1967 additions; total in place not reported.
d - Atlantic Coast Line and Seaboard Air Line railroads merged to form Seaboard Coast Line Railroad effective July 1, 1967. Statistics shown for Seaboard Coast Line include the separate operations of the two railroads.

Association of American Railroads
Economics and Finance Department
Washington, D. C. 20006

June 11, 1968

Table D

TREATED CROSS TIE UNIT PRICES

15 Selected Class I Railroads

District / Description of cross tie	Jan 1, 1967	Apr. 1, 1967	Jul. 1, 1967	Oct. 1, 1967	Jan 1, 1968
EAST:					
7"x9"x8'6" oak	$5.28	$5.28	$5.33	$5.33	$5.33
7"x9"x8'6" oak	5.70	5.70	5.70	5.70	5.65
7"x9"x8'6" mixed hardwood	5.80	5.80	5.80	5.80	5.80
7"x9"x8'6" oak	5.80	5.80	5.80	5.80	6.00
SOUTH:					
6"x8", 7"x8" and 7"x9" by 8'6" oak & mixed hardwood	4.03	3.67	3.85	4.08	4.08
7"x9"x9' mixed hardwood	4.80	4.80	4.80	4.80	4.80
7'x9'x8'6" mixed hardwood	4.77	4.90	4.90	4.94	4.94
7"x9"x8'6" oak	5.42	5.54	5.65	5.60	5.50
WEST:					
7"x9"x8'6" No. 1 & better Douglas fir	4.00	4.00	4.00	4.00	4.00
7"x9"x8'6" red oak	4.05	4.08	4.09	4.15	4.16
7"x9"x8' Douglas fir - No. 1 & better	4.36	4.41	4.35	4.39	4.39
7"x8"x9' hardwood	4.45	4.37	4.43	4.45	4.45
7"x9"x8'6" red or white oak	4.13	4.13	4.13	4.35	4.65
7"x9"x8'6" oak	5.18	5.18	5.18	5.18	5.18
7"x9"x8'6" hardwood	5.59	5.59	5.59	5.59	5.60

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